Refine Search

Search Results -

Terms	Documents
L2 and troubleshooting and expert adj knowledge and model$2	3

Database:
US Pre-Grant Publication Full-Text Database
US Patents Full-Text Database
US OCR Full-Text Database
EPO Abstracts Database
JPO Abstracts Database
Derwent World Patents Index
IBM Technical Disclosure Bulletins

Search: L4

Refine Search

Recall Text | Clear | Interrupt

Search History

DATE: Wednesday, April 21, 2004 Printable Copy Create Case

Set Name side by side	Query	Hit Count	Set Name result set
DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=NO; OP=OR			
L4	L2 and troubleshooting and expert adj knowledge and model$2	3	L4
L3	4,866,635.pn.	2	L3
L2	706/50.ccls.	224	L2
L1	20030004716	2	L1

END OF SEARCH HISTORY

Hit List

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Search Results - Record(s) 1 through 3 of 3 returned.

☐ 1. Document ID: US 6615199 B1

Using default format because multiple data bases are involved.

L4: Entry 1 of 3 File: USPT Sep 2, 2003

US-PAT-NO: 6615199
DOCUMENT-IDENTIFIER: US 6615199 B1
** See image for Certificate of Correction **

TITLE: Abstraction factory in a base services pattern environment

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 2. Document ID: US 5806056 A

L4: Entry 2 of 3 File: USPT Sep 8, 1998

US-PAT-NO: 5806056
DOCUMENT-IDENTIFIER: US 5806056 A

TITLE: Expert system and method employing hierarchical knowledge base, and interactive multimedia/hypermedia applications

DATE-ISSUED: September 8, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hekmatpour; Amir	Burlington	VT		

US-CL-CURRENT: 706/50; 706/45, 706/46, 706/61

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 3. Document ID: US 5720007 A

L4: Entry 3 of 3 File: USPT Feb 17, 1998

US-PAT-NO: 5720007
DOCUMENT-IDENTIFIER: US 5720007 A
**** See image for Certificate of Correction ****

TITLE: Expert system and method employing hierarchical knowledge base, and interactive multimedia/hypermedia applications

DATE-ISSUED: February 17, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hekmatpour; Amir	Burlington	VT		

US-CL-CURRENT: 706/50; 706/11, 706/46

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWMC | Draw De

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Terms	Documents
L2 and troubleshooting and expert adj knowledge and model$2	3

Display Format: - Change Format

Previous Page Next Page Go to Doc#

Refine Search

Search Results -

Terms	Documents
L2 and diagnos$3 and expert adj knowledge and model$2	9

Database:
US Pre-Grant Publication Full-Text Database
US Patents Full-Text Database
US OCR Full-Text Database
EPO Abstracts Database
JPO Abstracts Database
Derwent World Patents Index
IBM Technical Disclosure Bulletins

Search: L5

Refine Search

Recall Text | Clear | Interrupt

Search History

DATE: Wednesday, April 21, 2004 Printable Copy Create Case

Set Name side by side	Query	Hit Count	Set Name result set
DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=NO; OP=OR			
L5	L2 and diagnos$3 and expert adj knowledge and model$2	9	L5
L4	L2 and troubleshooting and expert adj knowledge and model$2	3	L4
L3	4,866,635.pn.	2	L3
L2	706/50.ccls.	224	L2
L1	20030004716	2	L1

END OF SEARCH HISTORY

Hit List

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Search Results - Record(s) 1 through 9 of 9 returned.

☐ 1. Document ID: US 6622136 B2

Using default format because multiple data bases are involved.

L5: Entry 1 of 9 File: USPT Sep 16, 2003

US-PAT-NO: 6622136
DOCUMENT-IDENTIFIER: US 6622136 B2

TITLE: Interactive tool for semi-automatic creation of a domain model

DATE-ISSUED: September 16, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Russell; Dale William	Palatine	IL		

US-CL-CURRENT: 706/45; 706/50, 706/61

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 2. Document ID: US 6615199 B1

L5: Entry 2 of 9 File: USPT Sep 2, 2003

US-PAT-NO: 6615199
DOCUMENT-IDENTIFIER: US 6615199 B1
**** See image for Certificate of Correction ****

TITLE: Abstraction factory in a base services pattern environment

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 3. Document ID: US 6356885 B2

L5: Entry 3 of 9 File: USPT Mar 12, 2002

US-PAT-NO: 6356885
DOCUMENT-IDENTIFIER: US 6356885 B2

TITLE: Network model for alarm correlation

DATE-ISSUED: March 12, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ross; Niall	Nr Great Dunmow			GB
White; Anthony Richard Phillip	Bishops Stortford			GB

US-CL-CURRENT: 706/45; 706/47, 706/50, 706/61, 706/916, 706/917

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 4. Document ID: US 6282531 B1

L5: Entry 4 of 9 File: USPT Aug 28, 2001

US-PAT-NO: 6282531
DOCUMENT-IDENTIFIER: US 6282531 B1

TITLE: System for managing applied knowledge and workflow in multiple dimensions and contexts

DATE-ISSUED: August 28, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Haughton; John F.	Westford	MA		
Merenyi; Robert C.	Lexington	MA		
Harris; Jeff	Hampton	NH		
Sherman; Alexander	Brookline	MA		

US-CL-CURRENT: 706/50; 706/46, 706/59

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 5. Document ID: US 5806056 A

L5: Entry 5 of 9 File: USPT Sep 8, 1998

US-PAT-NO: 5806056
DOCUMENT-IDENTIFIER: US 5806056 A

TITLE: Expert system and method employing hierarchical knowledge base, and interactive multimedia/hypermedia applications

DATE-ISSUED: September 8, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hekmatpour; Amir	Burlington	VT		

US-CL-CURRENT: 706/50; 706/45, 706/46, 706/61

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 6. Document ID: US 5720007 A

L5: Entry 6 of 9 File: USPT Feb 17, 1998

US-PAT-NO: 5720007
DOCUMENT-IDENTIFIER: US 5720007 A
**** See image for Certificate of Correction ****

TITLE: Expert system and method employing hierarchical knowledge base, and interactive multimedia/hypermedia applications

DATE-ISSUED: February 17, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hekmatpour; Amir	Burlington	VT		

US-CL-CURRENT: 706/50; 706/11, 706/46

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 7. Document ID: US 5615112 A

L5: Entry 7 of 9 File: USPT Mar 25, 1997

US-PAT-NO: 5615112
DOCUMENT-IDENTIFIER: US 5615112 A

TITLE: Synthesized object-oriented entity-relationship (SOOER) model for coupled knowledge-base/database of image retrieval expert system (IRES)

DATE-ISSUED: March 25, 1997

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Liu Sheng; Olivia R.	Tucson	AZ		
Wei; Chih-Ping	Tucson	AZ		

Ozeki; Takeshi Foster City AZ

US-CL-CURRENT: 707/104.1; 706/11, 706/45, 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 8. Document ID: US 5418889 A

L5: Entry 8 of 9 File: USPT May 23, 1995

US-PAT-NO: 5418889
DOCUMENT-IDENTIFIER: US 5418889 A

TITLE: System for generating knowledge base in which sets of common causal relation knowledge are generated

DATE-ISSUED: May 23, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ito; Tatsuo	Yokohama			JP

US-CL-CURRENT: 706/59; 706/45, 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 9. Document ID: US 4847784 A

L5: Entry 9 of 9 File: USPT Jul 11, 1989

US-PAT-NO: 4847784
DOCUMENT-IDENTIFIER: US 4847784 A
** See image for Certificate of Correction **

TITLE: Knowledge based tutor

DATE-ISSUED: July 11, 1989

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Clancey; William J.	Portola Valley	CA		

US-CL-CURRENT: 706/50; 706/46, 706/903, 706/911, 706/916, 706/922

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Terms	Documents
L2 and diagnos$3 and expert adj knowledge and model$2	9

Display Format: - Change Format

Previous Page Next Page Go to Doc#

Refine Search

Search Results -

Terms	Documents
vehicle and diagnos$3 and knowledge and model$2 and adaptive and management and decision adj support	39

Database: US Pre-Grant Publication Full-Text Database; US Patents Full-Text Database; US OCR Full-Text Database; EPO Abstracts Database; JPO Abstracts Database; Derwent World Patents Index; IBM Technical Disclosure Bulletins

Search: L9

Refine Search | Recall Text | Clear | Interrupt

Search History

DATE: Wednesday, April 21, 2004 Printable Copy Create Case

Set Name side by side	Query	Hit Count	Set Name result set
DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=NO; OP=OR			
L9	vehicle and diagnos$3 and knowledge and model$2 and adaptive and management and decision adj support	39	L9
L8	L7 and adaptive and management	212	L8
L7	vehicle and diagnos$3 and knowledge and model$2	6397	L7
L6	L5 and vehicle	1	L6
L5	L2 and diagnos$3 and expert adj knowledge and model$2	9	L5
L4	L2 and troubleshooting and expert adj knowledge and model$2	3	L4
L3	4,866,635.pn.	2	L3
L2	706/50.ccls.	224	L2
L1	20030004716	2	L1

END OF SEARCH HISTORY

Hit List

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Search Results - Record(s) 1 through 39 of 39 returned.

☐ 1. Document ID: US 20030144884 A1

Using default format because multiple data bases are involved.

L9: Entry 1 of 39 File: PGPB Jul 31, 2003

PGPUB-DOCUMENT-NUMBER: 20030144884
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030144884 A1

TITLE: Computerized prescription system for gathering and presenting information relating to pharmaceuticals

PUBLICATION-DATE: July 31, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Mayaud, Christian	New Canaan	CT	US	

US-CL-CURRENT: 705/3

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

☐ 2. Document ID: US 20030065409 A1

L9: Entry 2 of 39 File: PGPB Apr 3, 2003

PGPUB-DOCUMENT-NUMBER: 20030065409
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030065409 A1

TITLE: Adaptively detecting an event of interest

PUBLICATION-DATE: April 3, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Raeth, Peter G.	Beavercreek	OH	US	
Bostick, Randall L.	Springboro	OH	US	
Bertke, Donald Allen	Beavercreek	OH	US	

US-CL-CURRENT: 700/31; 700/28, 700/30, 700/44

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 3. Document ID: US 20030058277 A1

L9: Entry 3 of 39 File: PGPB Mar 27, 2003

PGPUB-DOCUMENT-NUMBER: 20030058277
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030058277 A1

TITLE: A VIEW CONFIGURER IN A PRESENTATION SERVICES PATTERNS ENVIROMENT

PUBLICATION-DATE: March 27, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
BOWMAN-AMUAH, MICHEL K.	COLORADO SPRINGS	CO	US	

US-CL-CURRENT: 345/765

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 4. Document ID: US 20030028651 A1

L9: Entry 4 of 39 File: PGPB Feb 6, 2003

PGPUB-DOCUMENT-NUMBER: 20030028651
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030028651 A1

TITLE: Proprietary information utility

PUBLICATION-DATE: February 6, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Schreckengast, James O.	Fort Collins	CO	US	
Engberg, Anton I.	Auburn	CA	US	

US-CL-CURRENT: 709/229; 705/52

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 5. Document ID: US 20020184178 A1

L9: Entry 5 of 39 File: PGPB Dec 5, 2002

PGPUB-DOCUMENT-NUMBER: 20020184178
PGPUB-FILING-TYPE: new

DOCUMENT-IDENTIFIER: US 20020184178 A1

TITLE: Adaptive knowledge management system for vehicle trend monitoring, health management and preventive maintenance

PUBLICATION-DATE: December 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Tasooji, Amaneh	Tempe	AZ	US	
Haigh, Karen Z.	Greenfield	MN	US	
Reising, Dal Vernon C.	Coon Rapids	MN	US	

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 6. Document ID: US 20020042726 A1

L9: Entry 6 of 39 File: PGPB Apr 11, 2002

PGPUB-DOCUMENT-NUMBER: 20020042726
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020042726 A1

TITLE: Prescription management system

PUBLICATION-DATE: April 11, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Mayaud, Christian	New Canaan	CT	US	

US-CL-CURRENT: 705/2

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 7. Document ID: US 20020042725 A1

L9: Entry 7 of 39 File: PGPB Apr 11, 2002

PGPUB-DOCUMENT-NUMBER: 20020042725
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020042725 A1

TITLE: Computerized prescription system for gathering and presenting information relating to pharmaceuticals

PUBLICATION-DATE: April 11, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Mayaud, Christian	New Canaan	CT	US	

US-CL-CURRENT: 705/2

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 8. Document ID: US 20020010679 A1

L9: Entry 8 of 39 File: PGPB Jan 24, 2002

PGPUB-DOCUMENT-NUMBER: 20020010679
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020010679 A1

TITLE: Information record infrastructure, system and method

PUBLICATION-DATE: January 24, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Felsher, David Paul	Trumbull	CT	US	

US-CL-CURRENT: 705/51; 705/3

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 9. Document ID: US 20010032029 A1

L9: Entry 9 of 39 File: PGPB Oct 18, 2001

PGPUB-DOCUMENT-NUMBER: 20010032029
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010032029 A1

TITLE: System and method for infrastructure design

PUBLICATION-DATE: October 18, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Kauffman, Stuart	Santa Fe	NM	US	

US-CL-CURRENT: 700/99; 700/105, 700/106, 700/97, 705/7

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 10. Document ID: US 6715145 B1

L9: Entry 10 of 39 File: USPT Mar 30, 2004

US-PAT-NO: 6715145
DOCUMENT-IDENTIFIER: US 6715145 B1

TITLE: Processing pipeline in a base services pattern environment

DATE-ISSUED: March 30, 2004

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 718/101; 718/100, 719/316

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 11. Document ID: US 6640249 B1

L9: Entry 11 of 39 File: USPT Oct 28, 2003

US-PAT-NO: 6640249
DOCUMENT-IDENTIFIER: US 6640249 B1

TITLE: Presentation services patterns in a netcentric environment

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/228; 719/315

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 12. Document ID: US 6640244 B1

L9: Entry 12 of 39 File: USPT Oct 28, 2003

US-PAT-NO: 6640244
DOCUMENT-IDENTIFIER: US 6640244 B1

TITLE: Request batcher in a transaction services patterns environment

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/207; 707/10, 718/101

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 13. Document ID: US 6640238 B1

L9: Entry 13 of 39 File: USPT Oct 28, 2003

US-PAT-NO: 6640238
DOCUMENT-IDENTIFIER: US 6640238 B1

TITLE: Activity component in a presentation services patterns environment

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michael K.	Colorado Springs	CO		

US-CL-CURRENT: 709/201; 709/203, 709/223, 709/224

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 14. Document ID: US 6636242 B2

L9: Entry 14 of 39 File: USPT Oct 21, 2003

US-PAT-NO: 6636242
DOCUMENT-IDENTIFIER: US 6636242 B2

TITLE: View configurer in a presentation services patterns environment

DATE-ISSUED: October 21, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 345/764; 345/733, 345/744, 345/762, 345/765

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 15. Document ID: US 6615253 B1

L9: Entry 15 of 39 File: USPT Sep 2, 2003

US-PAT-NO: 6615253
DOCUMENT-IDENTIFIER: US 6615253 B1
** See image for Certificate of Correction **

TITLE: Efficient server side data retrieval for execution of client side applications

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/219; 707/100, 711/118

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 16. Document ID: US 6615199 B1

L9: Entry 16 of 39 File: USPT Sep 2, 2003

US-PAT-NO: 6615199
DOCUMENT-IDENTIFIER: US 6615199 B1
**** See image for Certificate of Correction ****

TITLE: Abstraction factory in a base services pattern environment

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 17. Document ID: US 6606660 B1

L9: Entry 17 of 39 File: USPT Aug 12, 2003

US-PAT-NO: 6606660
DOCUMENT-IDENTIFIER: US 6606660 B1

TITLE: Stream-based communication in a communication services patterns environment

DATE-ISSUED: August 12, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/227

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 18. Document ID: US 6601234 B1

L9: Entry 18 of 39 File: USPT Jul 29, 2003

US-PAT-NO: 6601234
DOCUMENT-IDENTIFIER: US 6601234 B1

TITLE: Attribute dictionary in a business logic services environment

DATE-ISSUED: July 29, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 717/108; 705/7, 717/107, 717/116

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 19. Document ID: US 6601192 B1

L9: Entry 19 of 39 File: USPT Jul 29, 2003

US-PAT-NO: 6601192
DOCUMENT-IDENTIFIER: US 6601192 B1

TITLE: Assertion component in environment services patterns

DATE-ISSUED: July 29, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/38

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 20. Document ID: US 6578068 B1

L9: Entry 20 of 39 File: USPT Jun 10, 2003

US-PAT-NO: 6578068
DOCUMENT-IDENTIFIER: US 6578068 B1

TITLE: Load balancer in environment services patterns

DATE-ISSUED: June 10, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/203; 709/226, 718/105

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 21. Document ID: US 6571282 B1

L9: Entry 21 of 39 File: USPT May 27, 2003

US-PAT-NO: 6571282
DOCUMENT-IDENTIFIER: US 6571282 B1

TITLE: Block-based communication in a communication services patterns environment

DATE-ISSUED: May 27, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/219; 707/10, 709/203, 719/329

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 22. Document ID: US 6550057 B1

L9: Entry 22 of 39 File: USPT Apr 15, 2003

US-PAT-NO: 6550057
DOCUMENT-IDENTIFIER: US 6550057 B1

TITLE: Piecemeal retrieval in an information services patterns environment

DATE-ISSUED: April 15, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 717/126; 700/80, 707/5, 717/101, 717/102, 717/108, 717/109, 717/113

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 23. Document ID: US 6549949 B1

L9: Entry 23 of 39 File: USPT Apr 15, 2003

US-PAT-NO: 6549949
DOCUMENT-IDENTIFIER: US 6549949 B1

TITLE: Fixed format stream in a communication services patterns environment

DATE-ISSUED: April 15, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/236; 709/246

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 24. Document ID: US 6539396 B1

L9: Entry 24 of 39 File: USPT Mar 25, 2003

US-PAT-NO: 6539396
DOCUMENT-IDENTIFIER: US 6539396 B1

TITLE: Multi-object identifier system and method for information service pattern environment

DATE-ISSUED: March 25, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 707/103R; 707/101, 707/102, 707/103X, 707/202, 707/203, 711/118

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 25. Document ID: US 6529948 B1

L9: Entry 25 of 39 File: USPT Mar 4, 2003

US-PAT-NO: 6529948
DOCUMENT-IDENTIFIER: US 6529948 B1

TITLE: Multi-object fetch component

DATE-ISSUED: March 4, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/217; 709/219

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 26. Document ID: US 6529909 B1

L9: Entry 26 of 39 File: USPT Mar 4, 2003

US-PAT-NO: 6529909
DOCUMENT-IDENTIFIER: US 6529909 B1
**** See image for Certificate of Correction ****

TITLE: Method for translating an object attribute converter in an information services patterns environment

DATE-ISSUED: March 4, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 707/10; 707/1

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 27. Document ID: US 6502213 B1

L9: Entry 27 of 39 File: USPT Dec 31, 2002

US-PAT-NO: 6502213
DOCUMENT-IDENTIFIER: US 6502213 B1
**** See image for Certificate of Correction ****

TITLE: System, method, and article of manufacture for a polymorphic exception handler in environment services patterns

DATE-ISSUED: December 31, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/49; 710/266, 710/268, 710/269

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 28. Document ID: US 6496850 B1

L9: Entry 28 of 39 File: USPT Dec 17, 2002

US-PAT-NO: 6496850
DOCUMENT-IDENTIFIER: US 6496850 B1

TITLE: Clean-up of orphaned server contexts

DATE-ISSUED: December 17, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/203; 707/102, 709/224, 709/228

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 29. Document ID: US 6477665 B1

L9: Entry 29 of 39 File: USPT Nov 5, 2002

US-PAT-NO: 6477665
DOCUMENT-IDENTIFIER: US 6477665 B1

TITLE: System, method, and article of manufacture for environment services patterns in a netcentic environment

DATE-ISSUED: November 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/39; 712/244

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 30. Document ID: US 6477580 B1

L9: Entry 30 of 39 File: USPT Nov 5, 2002

US-PAT-NO: 6477580
DOCUMENT-IDENTIFIER: US 6477580 B1

TITLE: Self-described stream in a communication services patterns environment

DATE-ISSUED: November 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/231; 709/236

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 31. Document ID: US 6442748 B1

L9: Entry 31 of 39 File: USPT Aug 27, 2002

US-PAT-NO: 6442748
DOCUMENT-IDENTIFIER: US 6442748 B1

TITLE: System, method and article of manufacture for a persistent state and persistent object separator in an information services patterns environment

DATE-ISSUED: August 27, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 717/108; 707/103R, 707/104.1, 707/9, 719/316

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 32. Document ID: US 6438594 B1

L9: Entry 32 of 39 File: USPT Aug 20, 2002

US-PAT-NO: 6438594
DOCUMENT-IDENTIFIER: US 6438594 B1

TITLE: Delivering service to a client via a locally addressable interface

DATE-ISSUED: August 20, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/225; 709/203, 709/217, 709/250

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 33. Document ID: US 6434628 B1

L9: Entry 33 of 39 File: USPT Aug 13, 2002

US-PAT-NO: 6434628
DOCUMENT-IDENTIFIER: US 6434628 B1

TITLE: Common interface for handling exception interface name with additional prefix and suffix for handling exceptions in environment services patterns

DATE-ISSUED: August 13, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/48; 714/1, 714/15

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 34. Document ID: US 6434568 B1

L9: Entry 34 of 39 File: USPT Aug 13, 2002

US-PAT-NO: 6434568
DOCUMENT-IDENTIFIER: US 6434568 B1

TITLE: Information services patterns in a netcentric environment

DATE-ISSUED: August 13, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 707/103R; 707/10, 709/203

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 35. Document ID: US 6339832 B1

L9: Entry 35 of 39 File: USPT Jan 15, 2002

US-PAT-NO: 6339832
DOCUMENT-IDENTIFIER: US 6339832 B1

TITLE: Exception response table in environment services patterns

DATE-ISSUED: January 15, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/35; 710/266, 710/48, 714/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 36. Document ID: US 6332163 B1

L9: Entry 36 of 39 File: USPT Dec 18, 2001

US-PAT-NO: 6332163
DOCUMENT-IDENTIFIER: US 6332163 B1

TITLE: Method for providing communication services over a computer network system

DATE-ISSUED: December 18, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/231; 709/217, 709/223, 709/227, 719/329

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 37. Document ID: US 6289382 B1

L9: Entry 37 of 39 File: USPT Sep 11, 2001

US-PAT-NO: 6289382
DOCUMENT-IDENTIFIER: US 6289382 B1

TITLE: System, method and article of manufacture for a globally addressable interface in a communication services patterns environment

DATE-ISSUED: September 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/226

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 38. Document ID: US 5845255 A

L9: Entry 38 of 39 File: USPT Dec 1, 1998

US-PAT-NO: 5845255
DOCUMENT-IDENTIFIER: US 5845255 A

TITLE: Prescription management system

DATE-ISSUED: December 1, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Mayaud; Christian	New Canaan	CT		

US-CL-CURRENT: 705/3

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 39. Document ID: US 5737539 A

L9: Entry 39 of 39 File: USPT Apr 7, 1998

US-PAT-NO: 5737539
DOCUMENT-IDENTIFIER: US 5737539 A

TITLE: Prescription creation system

DATE-ISSUED: April 7, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Edelson; Jonathan	Scarsdale	NY		
Mayaud; Christian	New Canaan	CT		

US-CL-CURRENT: 705/3; 705/2

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Terms	Documents
vehicle and diagnos$3 and knowledge and model$2 and adaptive and management and decision adj support	39

Display Format: - Change Format

Previous Page Next Page Go to Doc#

Refine Search

Search Results -

Terms	Documents
L2 and knowledge and model$3 and vehicle and decision and feedback	3

Database: US Pre-Grant Publication Full-Text Database; US Patents Full-Text Database; US OCR Full-Text Database; EPO Abstracts Database; JPO Abstracts Database; Derwent World Patents Index; IBM Technical Disclosure Bulletins

Search: L11

Refine Search | Recall Text | Clear | Interrupt

Search History

DATE: Wednesday, April 21, 2004 Printable Copy Create Case

Set Name side by side	Query	Hit Count	Set Name result set
DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=NO; OP=OR			
L11	L2 and knowledge and model$3 and vehicle and decision and feedback	3	L11
L10	L2 and knowledge and model$3 and vehicle and decision adj making and feedback	1	L10
L9	vehicle and diagnos$3 and knowledge and model$2 and adaptive and management and decision adj support	39	L9
L8	L7 and adaptive and management	212	L8
L7	vehicle and diagnos$3 and knowledge and model$2	6397	L7
L6	L5 and vehicle	1	L6
L5	L2 and diagnos$3 and expert adj knowledge and model$2	9	L5
L4	L2 and troubleshooting and expert adj knowledge and model$2	3	L4
L3	4,866,635.pn.	2	L3
L2	706/50.ccls.	224	L2
L1	20030004716	2	L1

END OF SEARCH HISTORY

Hit List

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Search Results - Record(s) 1 through 3 of 3 returned.

☐ 1. Document ID: US 20020184178 A1

Using default format because multiple data bases are involved.

L11: Entry 1 of 3 File: PGPB Dec 5, 2002

PGPUB-DOCUMENT-NUMBER: 20020184178
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020184178 A1

TITLE: Adaptive knowledge management system for vehicle trend monitoring, health management and preventive maintenance

PUBLICATION-DATE: December 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Tasooji, Amaneh	Tempe	AZ	US	
Haigh, Karen Z.	Greenfield	MN	US	
Reising, Dal Vernon C.	Coon Rapids	MN	US	

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 2. Document ID: US 6615199 B1

L11: Entry 2 of 3 File: USPT Sep 2, 2003

US-PAT-NO: 6615199
DOCUMENT-IDENTIFIER: US 6615199 B1
** See image for Certificate of Correction **

TITLE: Abstraction factory in a base services pattern environment

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 3. Document ID: US 5903886 A

L11: Entry 3 of 3 File: USPT May 11, 1999

US-PAT-NO: 5903886
DOCUMENT-IDENTIFIER: US 5903886 A

TITLE: Hierarchical adaptive state machine for emulating and augmenting software

DATE-ISSUED: May 11, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Heimlich; Michael C.	Londonderry	NH		
St. Hilaire; Kenneth R.	Hollis	NH		

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Terms	Documents
L2 and knowledge and model$3 and vehicle and decision and feedback	3

Display Format: - Change Format

Previous Page Next Page Go to Doc#

Refine Search

Search Results -

Terms	Documents
L15 and interpreting	40

Database:
US Pre-Grant Publication Full-Text Database
US Patents Full-Text Database
US OCR Full-Text Database
EPO Abstracts Database
JPO Abstracts Database
Derwent World Patents Index
IBM Technical Disclosure Bulletins

Search: L16

Refine Search

Recall Text | Clear | Interrupt

Search History

DATE: Wednesday, April 21, 2004 Printable Copy Create Case

Set Name side by side	Query	Hit Count	Set Name result set
DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=NO; OP=OR			
L16	L15 and interpreting	40	L16
L15	L13 and diagnos$4	145	L15
L14	L13 diagnos$4	346684	L14
L13	L12 and real adj time and user and monitoring and capturing	191	L13
L12	knowledge and model$3 and vehicle and decision and feedback	825	L12
L11	L2 and knowledge and model$3 and vehicle and decision and feedback	3	L11
L10	L2 and knowledge and model$3 and vehicle and decision adj making and feedback	1	L10
L9	vehicle and diagnos$3 and knowledge and model$2 and adaptive and management and decision adj support	39	L9
L8	L7 and adaptive and management	212	L8
L7	vehicle and diagnos$3 and knowledge and model$2	6397	L7
L6	L5 and vehicle	1	L6

L5	L2 and diagnos$3 and expert adj knowledge and model$2	9	L5
L4	L2 and troubleshooting and expert adj knowledge and model$2	3	L4
L3	4,866,635.pn.	2	L3
L2	706/50.ccls.	224	L2
L1	20030004716	2	L1

END OF SEARCH HISTORY

Hit List

Clear | Generate Collection | Print | Fwd Refs | Bkwd Refs | Generate OACS

Search Results - Record(s) 1 through 40 of 40 returned.

☐ 1. Document ID: US 20030085621 A1

Using default format because multiple data bases are involved.

L16: Entry 1 of 40 File: PGPB May 8, 2003

PGPUB-DOCUMENT-NUMBER: 20030085621
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030085621 A1

TITLE: Power supply methods and configurations

PUBLICATION-DATE: May 8, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Potega, Patrick Henry	West Hills	CA	US	

US-CL-CURRENT: 307/18

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 2. Document ID: US 20030076369 A1

L16: Entry 2 of 40 File: PGPB Apr 24, 2003

PGPUB-DOCUMENT-NUMBER: 20030076369
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030076369 A1

TITLE: System and method for presentation of remote information in ambient form

PUBLICATION-DATE: April 24, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Resner, Benjamin I.	Roxbury	MA	US	
Rose, David L.	Cambridge	MA	US	
Gandhi, Pritesh V.	Allston	MA	US	
Hyatt, Nabeel	Boston	MA	US	
McRobbie, Christopher	Brookline	MA	US	

US-CL-CURRENT: 345/864; 709/217

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 3. Document ID: US 20030058277 A1

L16: Entry 3 of 40 File: PGPB Mar 27, 2003

PGPUB-DOCUMENT-NUMBER: 20030058277
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030058277 A1

TITLE: A VIEW CONFIGURER IN A PRESENTATION SERVICES PATTERNS ENVIROMENT

PUBLICATION-DATE: March 27, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
BOWMAN-AMUAH, MICHEL K.	COLORADO SPRINGS	CO	US	

US-CL-CURRENT: 345/765

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 4. Document ID: US 20020184178 A1

L16: Entry 4 of 40 File: PGPB Dec 5, 2002

PGPUB-DOCUMENT-NUMBER: 20020184178
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020184178 A1

TITLE: Adaptive knowledge management system for vehicle trend monitoring, health management and preventive maintenance

PUBLICATION-DATE: December 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Tasooji, Amaneh	Tempe	AZ	US	
Haigh, Karen Z.	Greenfield	MN	US	
Reising, Dal Vernon C.	Coon Rapids	MN	US	

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 5. Document ID: US 20020151992 A1

L16: Entry 5 of 40 File: PGPB Oct 17, 2002

PGPUB-DOCUMENT-NUMBER: 20020151992
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020151992 A1

TITLE: Media recording device with packet data interface

PUBLICATION-DATE: October 17, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Hoffberg, Steven M.	West Harrison	NY	US	
Hoffberg-Borghesani, Linda I.	Acton	MA	US	

US-CL-CURRENT: 700/83; 700/17, 700/18, 700/86, 700/87

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

☐ 6. Document ID: US 20010056359 A1

L16: Entry 6 of 40 File: PGPB Dec 27, 2001

PGPUB-DOCUMENT-NUMBER: 20010056359
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010056359 A1

TITLE: System and method for communicating product recall information, product warnings or other product-related information to users of products

PUBLICATION-DATE: December 27, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Abreu, Marcio Marc	North Haven	CT	US	

US-CL-CURRENT: 705/3

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

☐ 7. Document ID: US 6715145 B1

L16: Entry 7 of 40 File: USPT Mar 30, 2004

US-PAT-NO: 6715145
DOCUMENT-IDENTIFIER: US 6715145 B1

TITLE: Processing pipeline in a base services pattern environment

DATE-ISSUED: March 30, 2004

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 718/101; 718/100, 719/316

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 8. Document ID: US 6640249 B1

L16: Entry 8 of 40 File: USPT Oct 28, 2003

US-PAT-NO: 6640249
DOCUMENT-IDENTIFIER: US 6640249 B1

TITLE: Presentation services patterns in a netcentric environment

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/228; 719/315

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 9. Document ID: US 6640244 B1

L16: Entry 9 of 40 File: USPT Oct 28, 2003

US-PAT-NO: 6640244
DOCUMENT-IDENTIFIER: US 6640244 B1

TITLE: Request batcher in a transaction services patterns environment

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/207; 707/10, 718/101

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 10. Document ID: US 6640238 B1

L16: Entry 10 of 40 File: USPT Oct 28, 2003

US-PAT-NO: 6640238
DOCUMENT-IDENTIFIER: US 6640238 B1

TITLE: Activity component in a presentation services patterns environment

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michael K.	Colorado Springs	CO		

US-CL-CURRENT: 709/201; 709/203, 709/223, 709/224

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 11. Document ID: US 6640145 B2

L16: Entry 11 of 40 File: USPT Oct 28, 2003

US-PAT-NO: 6640145
DOCUMENT-IDENTIFIER: US 6640145 B2

TITLE: Media recording device with packet data interface

DATE-ISSUED: October 28, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoffberg; Steven	West Harrison	NY	10604	
Hoffberg-Borghesani; Linda	Acton	MA	01720	

US-CL-CURRENT: 700/83; 700/17, 700/19, 700/23, 704/200, 704/201, 704/7, 709/200, 709/201, 709/202

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 12. Document ID: US 6636242 B2

L16: Entry 12 of 40 File: USPT Oct 21, 2003

US-PAT-NO: 6636242
DOCUMENT-IDENTIFIER: US 6636242 B2

TITLE: View configurer in a presentation services patterns environment

DATE-ISSUED: October 21, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 345/764; 345/733, 345/744, 345/762, 345/765

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 13. Document ID: US 6615253 B1

L16: Entry 13 of 40 File: USPT Sep 2, 2003

US-PAT-NO: 6615253
DOCUMENT-IDENTIFIER: US 6615253 B1
**** See image for Certificate of Correction ****

TITLE: Efficient server side data retrieval for execution of client side applications

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/219; 707/100, 711/118

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 14. Document ID: US 6615199 B1

L16: Entry 14 of 40 File: USPT Sep 2, 2003

US-PAT-NO: 6615199
DOCUMENT-IDENTIFIER: US 6615199 B1
**** See image for Certificate of Correction ****

TITLE: Abstraction factory in a base services pattern environment

DATE-ISSUED: September 2, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 15. Document ID: US 6606660 B1

L16: Entry 15 of 40 File: USPT Aug 12, 2003

US-PAT-NO: 6606660

DOCUMENT-IDENTIFIER: US 6606660 B1

TITLE: Stream-based communication in a communication services patterns environment

DATE-ISSUED: August 12, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/227

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 16. Document ID: US 6601234 B1

L16: Entry 16 of 40 File: USPT Jul 29, 2003

US-PAT-NO: 6601234
DOCUMENT-IDENTIFIER: US 6601234 B1

TITLE: Attribute dictionary in a business logic services environment

DATE-ISSUED: July 29, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 717/108; 705/7, 717/107, 717/116

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 17. Document ID: US 6601192 B1

L16: Entry 17 of 40 File: USPT Jul 29, 2003

US-PAT-NO: 6601192
DOCUMENT-IDENTIFIER: US 6601192 B1

TITLE: Assertion component in environment services patterns

DATE-ISSUED: July 29, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/38

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 18. Document ID: US 6578068 B1

L16: Entry 18 of 40 File: USPT Jun 10, 2003

US-PAT-NO: 6578068
DOCUMENT-IDENTIFIER: US 6578068 B1

TITLE: Load balancer in environment services patterns

DATE-ISSUED: June 10, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/203; 709/226, 718/105

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 19. Document ID: US 6571282 B1

L16: Entry 19 of 40 File: USPT May 27, 2003

US-PAT-NO: 6571282
DOCUMENT-IDENTIFIER: US 6571282 B1

TITLE: Block-based communication in a communication services patterns environment

DATE-ISSUED: May 27, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/219; 707/10, 709/203, 719/329

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 20. Document ID: US 6550057 B1

L16: Entry 20 of 40 File: USPT Apr 15, 2003

US-PAT-NO: 6550057
DOCUMENT-IDENTIFIER: US 6550057 B1

TITLE: Piecemeal retrieval in an information services patterns environment

DATE-ISSUED: April 15, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 717/126; 700/80, 707/5, 717/101, 717/102, 717/108, 717/109, 717/113

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 21. Document ID: US 6549949 B1

L16: Entry 21 of 40 File: USPT Apr 15, 2003

US-PAT-NO: 6549949
DOCUMENT-IDENTIFIER: US 6549949 B1

TITLE: Fixed format stream in a communication services patterns environment

DATE-ISSUED: April 15, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/236; 709/246

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 22. Document ID: US 6539396 B1

L16: Entry 22 of 40 File: USPT Mar 25, 2003

US-PAT-NO: 6539396
DOCUMENT-IDENTIFIER: US 6539396 B1

TITLE: Multi-object identifier system and method for information service pattern environment

DATE-ISSUED: March 25, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 707/103R; 707/101, 707/102, 707/103X, 707/202, 707/203, 711/118

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 23. Document ID: US 6529948 B1

L16: Entry 23 of 40 File: USPT Mar 4, 2003

US-PAT-NO: 6529948
DOCUMENT-IDENTIFIER: US 6529948 B1

TITLE: Multi-object fetch component

DATE-ISSUED: March 4, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/217; 709/219

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 24. Document ID: US 6529909 B1

L16: Entry 24 of 40 File: USPT Mar 4, 2003

US-PAT-NO: 6529909
DOCUMENT-IDENTIFIER: US 6529909 B1
**** See image for Certificate of Correction ****

TITLE: Method for translating an object attribute converter in an information services patterns environment

DATE-ISSUED: March 4, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 707/10; 707/1

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 25. Document ID: US 6502213 B1

L16: Entry 25 of 40 File: USPT Dec 31, 2002

US-PAT-NO: 6502213
DOCUMENT-IDENTIFIER: US 6502213 B1
**** See image for Certificate of Correction ****

TITLE: System, method, and article of manufacture for a polymorphic exception handler in environment services patterns

DATE-ISSUED: December 31, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/49; 710/266, 710/268, 710/269

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw Ds

☐ 26. Document ID: US 6496850 B1

L16: Entry 26 of 40 File: USPT Dec 17, 2002

US-PAT-NO: 6496850
DOCUMENT-IDENTIFIER: US 6496850 B1

TITLE: Clean-up of orphaned server contexts

DATE-ISSUED: December 17, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/203; 707/102, 709/224, 709/228

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw Ds

☐ 27. Document ID: US 6477665 B1

L16: Entry 27 of 40 File: USPT Nov 5, 2002

US-PAT-NO: 6477665
DOCUMENT-IDENTIFIER: US 6477665 B1

TITLE: System, method, and article of manufacture for environment services patterns in a netcentic environment

DATE-ISSUED: November 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/39; 712/244

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw Ds

☐ 28. Document ID: US 6477580 B1

L16: Entry 28 of 40 File: USPT Nov 5, 2002

US-PAT-NO: 6477580
DOCUMENT-IDENTIFIER: US 6477580 B1

TITLE: Self-described stream in a communication services patterns environment

DATE-ISSUED: November 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/231; 709/236

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 29. Document ID: US 6442748 B1

L16: Entry 29 of 40 File: USPT Aug 27, 2002

US-PAT-NO: 6442748
DOCUMENT-IDENTIFIER: US 6442748 B1

TITLE: System, method and article of manufacture for a persistent state and persistent object separator in an information services patterns environment

DATE-ISSUED: August 27, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 717/108; 707/103R, 707/104.1, 707/9, 719/316

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 30. Document ID: US 6438594 B1

L16: Entry 30 of 40 File: USPT Aug 20, 2002

US-PAT-NO: 6438594
DOCUMENT-IDENTIFIER: US 6438594 B1

TITLE: Delivering service to a client via a locally addressable interface

DATE-ISSUED: August 20, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/225; 709/203, 709/217, 709/250

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 31. Document ID: US 6434628 B1

L16: Entry 31 of 40 File: USPT Aug 13, 2002

US-PAT-NO: 6434628
DOCUMENT-IDENTIFIER: US 6434628 B1

TITLE: Common interface for handling exception interface name with additional prefix and suffix for handling exceptions in environment services patterns

DATE-ISSUED: August 13, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/48; 714/1, 714/15

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 32. Document ID: US 6434568 B1

L16: Entry 32 of 40 File: USPT Aug 13, 2002

US-PAT-NO: 6434568
DOCUMENT-IDENTIFIER: US 6434568 B1

TITLE: Information services patterns in a netcentric environment

DATE-ISSUED: August 13, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 707/103R; 707/10, 709/203

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 33. Document ID: US 6418424 B1

L16: Entry 33 of 40 File: USPT Jul 9, 2002

US-PAT-NO: 6418424
DOCUMENT-IDENTIFIER: US 6418424 B1

TITLE: Ergonomic man-machine interface incorporating adaptive pattern recognition based control system

DATE-ISSUED: July 9, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoffberg; Steven M.	West Harrison	NY	10604	
Hoffberg-Borghesani; Linda I.	Acton	MA	01720	

US-CL-CURRENT: 706/21; 434/178, 706/52

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 34. Document ID: US 6400996 B1

L16: Entry 34 of 40 File: USPT Jun 4, 2002

US-PAT-NO: 6400996
DOCUMENT-IDENTIFIER: US 6400996 B1

TITLE: Adaptive pattern recognition based control system and method

DATE-ISSUED: June 4, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoffberg; Steven M.	West Harrison	NY	10994	
Hoffberg-Borghesani; Linda I.	Acton	MA	01720	

US-CL-CURRENT: 700/83; 345/810, 345/840, 345/841, 370/218, 370/355, 700/17, 700/24, 700/25, 700/86, 700/87, 709/223, 709/227, 718/102, 719/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 35. Document ID: US 6339832 B1

L16: Entry 35 of 40 File: USPT Jan 15, 2002

US-PAT-NO: 6339832
DOCUMENT-IDENTIFIER: US 6339832 B1

TITLE: Exception response table in environment services patterns

DATE-ISSUED: January 15, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 714/35; 710/266, 710/48, 714/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 36. Document ID: US 6332163 B1

L16: Entry 36 of 40 File: USPT Dec 18, 2001

US-PAT-NO: 6332163
DOCUMENT-IDENTIFIER: US 6332163 B1

TITLE: Method for providing communication services over a computer network system

DATE-ISSUED: December 18, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/231; 709/217, 709/223, 709/227, 719/329

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 37. Document ID: US 6289382 B1

L16: Entry 37 of 40 File: USPT Sep 11, 2001

US-PAT-NO: 6289382
DOCUMENT-IDENTIFIER: US 6289382 B1

TITLE: System, method and article of manufacture for a globally addressable interface in a communication services patterns environment

DATE-ISSUED: September 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bowman-Amuah; Michel K.	Colorado Springs	CO		

US-CL-CURRENT: 709/226

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 38. Document ID: US 6081750 A

L16: Entry 38 of 40 File: USPT Jun 27, 2000

US-PAT-NO: 6081750
DOCUMENT-IDENTIFIER: US 6081750 A

TITLE: Ergonomic man-machine interface incorporating adaptive pattern recognition based control system

DATE-ISSUED: June 27, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoffberg; Steven Mark	Yonkers	NY	10701-1705	
Hoffberg-Borghesani; Linda Irene	Acton	MA	01720	

US-CL-CURRENT: 700/17; 345/520, 700/11, 700/56, 700/83, 700/86

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 39. Document ID: US 5901246 A

L16: Entry 39 of 40 File: USPT May 4, 1999

US-PAT-NO: 5901246
DOCUMENT-IDENTIFIER: US 5901246 A

TITLE: Ergonomic man-machine interface incorporating adaptive pattern recognition based control system

DATE-ISSUED: May 4, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoffberg; Steven M.	Yonkers	NY	10701-1705	
Hoffberg-Borghesani; Linda I.	Acton	MA	01720	

US-CL-CURRENT: 382/209

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 40. Document ID: US 5875108 A

L16: Entry 40 of 40 File: USPT Feb 23, 1999

US-PAT-NO: 5875108
DOCUMENT-IDENTIFIER: US 5875108 A

TITLE: Ergonomic man-machine interface incorporating adaptive pattern recognition based control system

DATE-ISSUED: February 23, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hoffberg; Steven M.	Yonkers	NY	10701-1705	
Hoffberg-Borghesani; Linda I.	Acton	MA	01720	

US-CL-CURRENT: 700/17; 382/181, 382/190, 700/83

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

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☐ 1. Document ID: US 20020184178 A1

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L17: Entry 1 of 2 File: PGPB Dec 5, 2002

PGPUB-DOCUMENT-NUMBER: 20020184178
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020184178 A1

TITLE: Adaptive knowledge management system for vehicle trend monitoring, health management and preventive maintenance

PUBLICATION-DATE: December 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Tasooji, Amaneh	Tempe	AZ	US	
Haigh, Karen Z.	Greenfield	MN	US	
Reising, Dal Vernon C.	Coon Rapids	MN	US	

US-CL-CURRENT: 706/50

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWMC | Draw De

☐ 2. Document ID: US 5724987 A

L17: Entry 2 of 2 File: USPT Mar 10, 1998

US-PAT-NO: 5724987
DOCUMENT-IDENTIFIER: US 5724987 A

TITLE: Neurocognitive adaptive computer-aided training method and system

DATE-ISSUED: March 10, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Gevins; Alan	San Francisco	CA		
Leong; Harrison	San Francisco	CA		
Sam-Vargas; Isabel	San Francisco	CA		
Smith; Michael	San Francisco	CA		

US-CL-CURRENT: 600/544; 434/258

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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... **Adaptive Knowledge Management system** for Vehicle Trend Monitoring, Health Management and Preventative Maintenance. Honeywell patent docket H0001338. ...
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Wednesday, April 21, 2004

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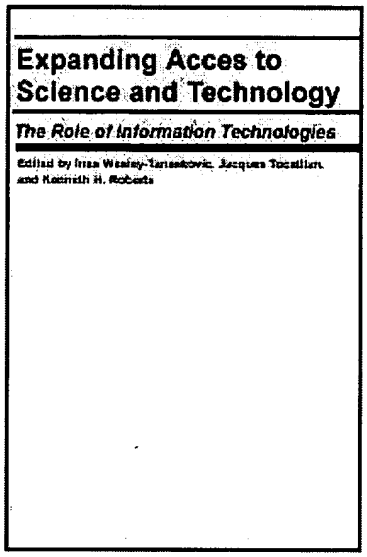
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Expanding access to science and technology

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Edited by
Ines Wesley-Tanaskovic, Jacques Tocatlian, and Kenneth H. Roberts

Expanding Access to Science and Technology: The Role of Information Technologies

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Simulated man-machine systems as computer-aided information transfer and self-learning tools
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Simulated man-machine systems as computer-aided information transfer and self-learning tools

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Gunnar Johannsen

Abstract

Several negative side-effects of socio-technical changes in industrialized as well as in developing countries are recognized. The potential of information technology for bettering these situations is discussed, particularly with respect to improved training for acquainting people with technical systems and their practical use. Human interaction with integrated automation in man-machine systems is surveyed. This involves discussion of control and problem-solving tasks, decision-support systems, man-machine interfaces, and several stages of knowledge transfer. The main contribution of the paper deals with knowledge-based information access by means of simulation and self-learning tools. The author suggests simulated man-machine systems for training supervision and control tasks as well as computerized tools for self-learning of problem-solving tasks and for information transfer of broader man-machine systems engineering issues in a societal context. The cultural aspects of such tools as well as the needs for future research and for future socio-technical development are also emphasized.

1. Introduction

Presently we are living in times of rapid socio-technical changes with certain dangers of possible instabilities. These changes refer, on the one hand, to

- progress in science and technology, particularly in information and communication technologies, and, on the other, to
- inequalities in the standard of living, for example, with respect to food supply, housing, health care, and mobility, as well as in individual and social freedom,
- environmental and social consequences of thoughtless technological developments,
- the need for conversion of many military and very high-risk technologies, and
- the need for trust, responsibility, tolerance, and mutual support in individual, social, and international relations.

One may come to the conclusion that during the last two to three decades, many problems on our globe have worsened. Certainly, parts of the world have attained higher standards of living, more individual and social freedom, and higher mobility than ever experienced before. However, larger parts of the world are far from reaching these standards and have even suffered deteriorations in several cases. Thus, the poor and the developing countries are sometimes lagging further behind, and they see much larger gaps between themselves and the highly developed countries than a few decades ago.

What about the industrialized countries themselves? There, technological developments have also brought about a large number of negative long-term effects. Environmental problems due to the consumption of energy and materials, traffic, and waste (radioactive, toxic, and non-toxic) have created many concerns with respect to the future qualities of air, water, and soil. Other technological developments have led to social consequences such as unemployment, unreasonable distribution of work, and isolation. Traffic congestion in cities and on highways as well as fatal accidents with cars, aircraft, power plants, and industrial processes may remind us of our limited capabilities and understanding. Some experts have recently estimated that the delayed consequences of the reactor catastrophe of the Chernobyl nuclear power plant in 1986 will amount to between one and two million casualities over the next years. Additional risks have only started to become visible to the general public, since the end of the Cold War between the West and East blocs of the industrialized countries makes most of the industrial-military complex obsolete on both sides. The need for conversion of institutions, systems, and materials has been recognized as a huge challenge.

It seems that the amount of clearing work to be done in the near future will be overwhelming. To distrust science and technology because of their negative side-effects will certainly not be an appropriate solution. Instead, science and technology are badly needed to perform the clearing work in an appropriate way and also for improving the standard of living - substantially in poor and developing countries, but also moderately in developed countries. Often, several degrees of development exist within a single country. Therefore, suitable strategies are required that try to avoid earlier errors, when further developing technologies and societies. In order to accomplish this enormous task for mankind in the near future of the next two to three decades, we need a spirit of trust, responsibility, tolerance, and mutual sup port in individual, social, and international relations. And we all need to share in the extra work to be done as well as in the financial and socio-psychological burdens. I believe that information, communication, and truthfulness together with the adoption of a realistic long-term balance of costs and benefits will contribute to building up this spirit and the willingness to share as a prerequisite for peaceful developments.

Information and communication technologies will therefore play an important role for humane development all over the world. However, the very many possible misuses of these technologies need to be banned internationally as much as does the violation of human rights. Each individual human being must have the possibility of access to any information he or she wishes to receive and to understand.

Because of the many individual limits to understanding different kinds of information, special tools have to be available for navigating through the information.

In this paper, I will restrict myself to a special kind of tool for computer-aided information transfer and self-learning. Through a further restriction, the paper mainly concentrates on simulated man-machine systems that are to be used as information tools. They are dynamic and interactive and, thus, can demonstrate and teach how technical systems - the machines - are to be operated and maintained. Combined with regularly renewed licensing of human task responsibilities, such tools may possibly help to avoid at least some of the most fateful accidents. Before discussing these tools in more detail in section 3, the most prominent technical and cognitive aspects of man-machine systems will be introduced in section 2. The paper concludes in section 4 by pointing out the need for further work on realizing the suggested tools that now exist at best only in laboratory versions.

2. Human interaction with integrated automation in man-machine systems

2.1 Control and Problem-solving Tasks

All dynamic technical systems that are operated by one or several human beings can be viewed together with these human operators as man-machine systems. Thus, all kinds of vehicles, continuous and discrete industrial processes, power plants, robots and manipulators, business and public information systems, biomedical support systems, and many more are man-machine systems in this sense. To achieve the prescribed goals of safe and efficient operation of man-machine systems, two main categories of tasks, controlling and problem solving, have to be performed. In principle, both task categories can be performed by the human operator(s) as well as by automatic computerized systems.

The control activities comprise reaching, open-loop and closed-loop control in the narrower sense of control theory, monitoring, and lower supervisory control functions such as intervening in automated processes. On higher cognitive levels, problem-solving activities have to be performed. These include fault management, particularly with fault diagnosis and correction, goal setting and hypothesis generation, planning, and the higher supervisory control functions such as teaching. The distinction between control and problem-solving tasks is especially advocated by Johannsen [11,12]. The latter is a task-oriented concept, whereas the overlay of the supervisory control paradigm is an interaction-oriented concept. The latter consists of a hierarchical, decentralized structure with task-interactive computers at the lower level and human-interactive computer(s) at the coordinating, higher level [26]. The five generic supervisory control functions are planning, teaching, monitoring, intervening, and learning.

Different levels and phases of human and automatic controlling and problem solving (after ref. 13)

Behavioural levels	**State-oriented level**	**Context-oriented level**	**Structure-oriented level**
Information - processing phases			
Categorization	Signal (and alarm) detection, state estimation	Pattern recognition and matching, analysis of sequential observations	Situational and system identification
Planning	Fixed related (between categorization and	Script selection	Plan generation and adaption

	action)		
Action	Stereotyped automatic control	Symptomatic rule application	Topographic rule application

Human and automatic controlling and problem solving show several similarities, but there are also differences between both forms of the two task categories. A further classification of these task categories is illustrated in the table. The table shows human and automatic activities separated into three succeeding Information-processing phases, namely categorization, planning, and action (see also Rouse [21] and Sundström [30]). These information-processing phases can be cycled through on three distinct behavioural levels, namely the state-oriented, the context-oriented, and the structure-oriented levels, which correspond in some way to the cognitive levels of behaviour as suggested by Rasmussen [18, 19].

The main domains of automation systems are the complete state-oriented level as well as at least some parts of the categorization phase of the context-and structure-oriented levels. Of course, human operators can also be engaged in these activities. However, they are particularly superior to automation systems in the planning and action phases of the context-and structure-oriented levels. These areas of table 1 correspond more to the problem-solving tasks and, thus, require higher cognitive behaviour. This is even true when prescribed plans, so-called scripts, have to be selected and rules for actions have to be applied on the basis of observed symptoms. The human operator is particularly indispensable when new plans have to be generated and rules have to be applied on a topographic or completely structural relationship because an unforeseen situation has to be dealt with.

The recent aircraft accident near Stockholm is a good example of the latter case, although it also has elements of the context-oriented level. After the engines no longer worked as the aircraft neared the ground, the pilots had only a very short time to plan and execute an emergency landing on a field just behind a forest. All passengers survived because of the excellent human performance. Where to glide down with the aircraft had to be decided on the structure-oriented level, whereas many of the subordinated guidance and control activities were probably done with some kind of script selection. These scripts were built up during previous simulator training. It is a general policy that pilots are well trained by means of simulated critical events in order to build up more automated scripted behaviour that can be reproduced much faster than the generation of new plans but will hopefully never be needed in reality.

The higher cognitive functions as described with table 1 can also, at least partially, be handled with new information technologies. There are knowledge-based decision support systems. Similarly, like human operators, these decision support systems mainly process symbolic information about contexts and structures rather than numerical information about signals and states. Thus, it is necessary to realize some kind of signal-to-symbol transformations and vice versa to be performed by the human operator or the computerized system when freely navigating through the whole plane of table 1.

Appropriate function and task allocations determine which tasks will best be performed by the human operators and which will best be assigned to the computerized systems. With an integration between traditional automation systems and the more recent information technologies of the decision-support systems, human-centred designs and dynamic forms of task allocations are possible (see, e. g., Rouse (22]).

2.2 Integration between Traditional Automation and Decision-Support Systems

Human-centred designs of integrated automation will lead to improved man-machine systems in the

very near future. These perspectives occurred because of knowledge-based information technologies. The term integrated automation means that traditional automation systems and knowledge-based decision-support systems cooperate closely in a suitable way. The criteria for what is suitable, however, need to be defined and require the human-centred approach that is also part of the integrated automation concept.

As elaborated in more detail by Johannsen [11], an extended Operator (User) Interface Management System architecture for dynamic technical systems allows the description of the integrated automation concept with a number of separated levels (see also Alty and Johannsen [2]). Figure 1 shows these levels of the UIMS architecture. The features of man-machine interfaces will be reviewed in the next subsection. Here I discuss the different levels of the technical system as shown in figure 1. The information selector 1 processes numerical information, whereas the information selector 2 transforms signals into symbols for the information processing at the decision-support level. This level cooperates with the traditional automation of the supervision and control level.

Decision-support systems can be subdivided into those that are more application oriented and those that are more human operator oriented. In figure 1, they are called application model support and operator model support, respectively. The application model support systems deal with situations in the technical process and the supervision and control system. The information that is processed for these situations is then communicated to the human operator as a decision support. Operators will normally perform a dialogue with such decision-support systems in order to satisfy their information needs. These application model support systems can also be viewed with respect to the behavioural levels as suggested in table 1. Examples for these three levels are the decision support for heuristic control [17], for fault diagnosis (e.g., Borndorff-Eccarius [3]), and for plant management; see Johannsen [11] for more details.

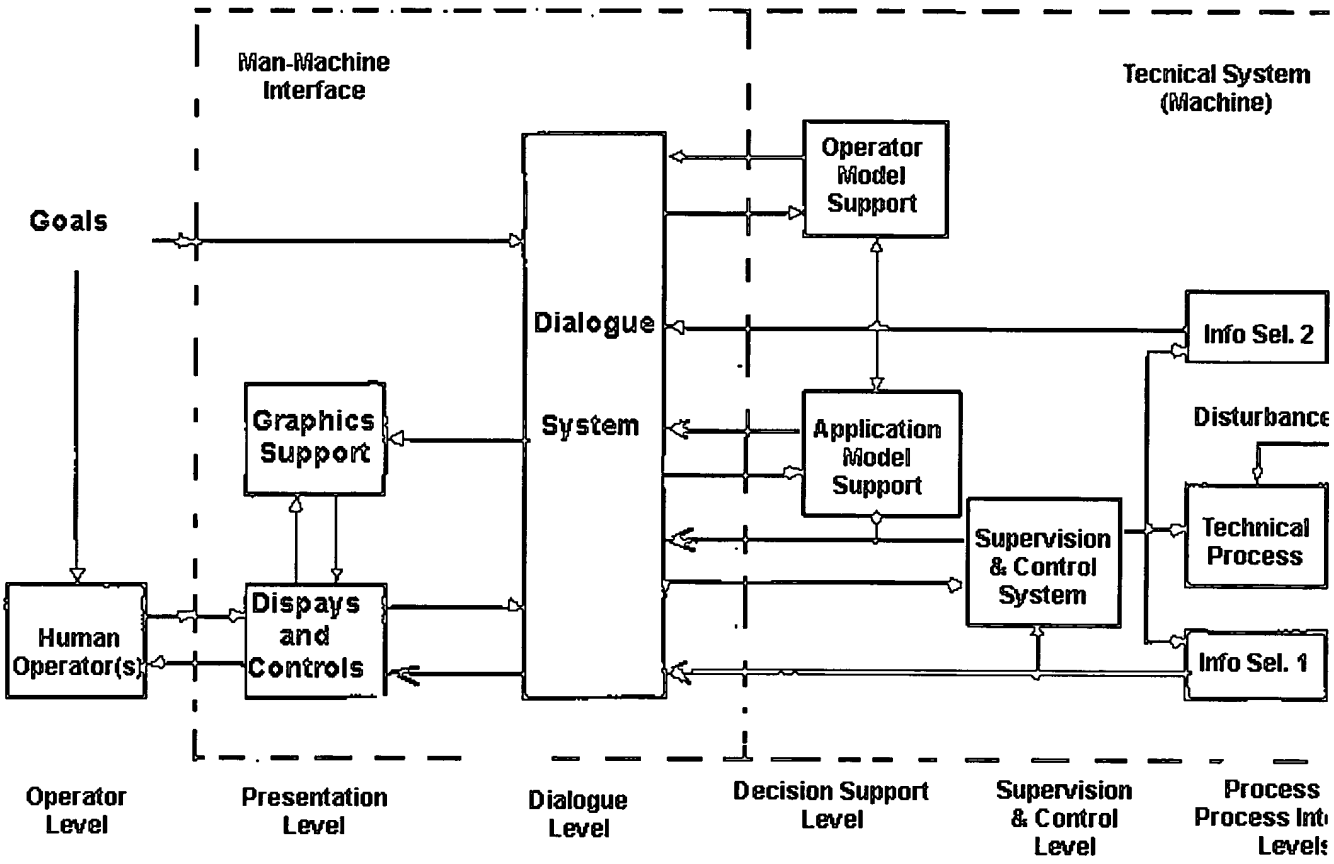
Similarly, the operator model support systems deal more directly with human operators' behaviour and help them to perform as well as possible. Again, three behavioural levels can be distinguished. Examples are human error evaluation (e.g., Hessler [9]), plan or intent recognition (e.g., Rubin et al. [24]), and procedural support (e.g., Sundström [30]); more details are given in Johannsen [11].

A mathematical framework for interaction between traditional automation and decision-support systems is supplied by Johannsen [11] and explained with four case-studies. This mathematical framework requires much more precision and details that can only become available after a lot of further multidisciplinary research.

2.3 Man-Machine interfaces with Graphical and Dialogue Support

The presentation level and the dialogue level describe the two distinct aspects of any man-machine interface, as shown in figure 1. The presentation level concerns the form of the information and, thus, includes the displays and controls, which are more and more often computer graphics screens and computerized control input systems, as well as some knowledge-based graphics support modules. The dialogue system is a kind of central intermediary between the human operator(s) and all levels of the whole technical system, including the decision-support systems, and deals with the contents of information flows in the man-machine communication. Loose ends of dialogue can occur, particularly in critical situations, when an urgent request of a subsystem of the technical system interrupts the interaction of another one with the human operator [2]. Handling these loose ends of dialogue can be supported by small-scale knowledge-based dialogue assistants for the interaction with the different subsystems of the technical system.

Figure 1 Extended Operator (User) Interface Management System structure for dynamic technical systems (after Johannsen, 1992)



The visual display units with colour graphics screens allow flexible and task-adapted forms of presentation. Many options for picture design exist, but the multitude of alternatives can also be misused if the designers lack enough knowledge about ergonomics and the information needs of human operators [10]. Dynamical shifts of information needs in the problem space of the two dimensions of the degree of detail and of the level of abstraction must be taken into account even more with advanced information display concepts, as already suggested by Goodstein [8]. The design of graphics support can lead to knowledge-based graphical systems that dynamically generate new picture contents by using knowledge of the application, of the operator model based on information search needs, of graphical presentation techniques, and of dialogue techniques. Such concepts require an integration of computer graphics and knowledge-based technologies [5, 6]. A similar approach for knowledge-based designer support and intelligent man-machine interfaces for process control was suggested by Tendjaoui, Kolski, and Millot [32]. The cognitive engineering approach must also be applied here to answer the question of how to present information to the human operator(s) and to design appropriate graphical decision support for the goal-directed, spatial visualization of task-meaningful units and their relations [34]. The searcher for which interaction media to use has, among others, to consider recent results on multimedia research [1].

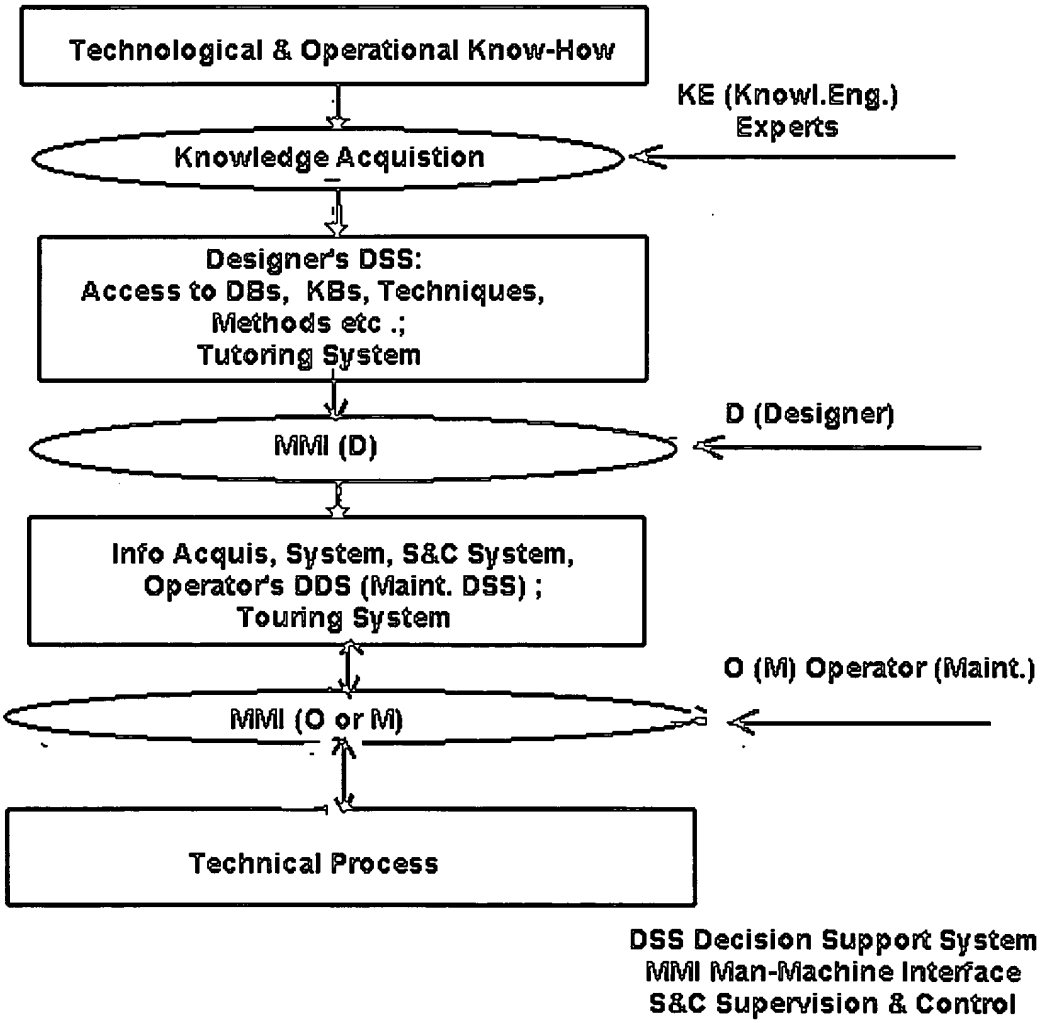
Advanced man-machine interfaces that integrate knowledge-based task and operator models as decision-support systems with presentation and dialogue submodules were particularly investigated by Tendjaoui, Kolski, and Millot [32] and by Sundström [30], and reviewed by Johannsen [11]. Application and process knowledge as well as ergonomic knowledge and knowledge about the information search needs of the human operator(s) in different operational situations determine which information needs to be displayed, when, and how. In principle, cooperative interactions between several human operators and

the knowledge-based decision-support systems are possible. However, the state of the technology has not yet advanced to the level of rigorous industrial applications.

2.4 Transformation and Use of Knowledge by Knowledge Engineers, Designers, and Operators

Human operators do not use only their own knowledge in interactions within man-machine systems. In addition, a lot of knowledge is available to them directly or indirectly through the information acquisition system, the supervision and control system, and the decision-support systems. Much of this knowledge has been supplied by the designers of these systems. The maintenance personnel find themselves in a similar situation; however, the decision-support systems, as well as the man-machine interfaces designed for them, may be different from those for the human operators. This is indicated in the lower part of figure 2. The figure also shows that in addition, a tutoring system may have been designed to teach novices how to operate or to maintain the whole technical system.

Figure 2 Stages of knowledge transfer and man-machine interaction for knowledge engineers, designers, operators, and maintenance personnel



The designer creates knowledge support implemented in the different subsystems for the human operators and the maintenance personnel. Similarly, the designers themselves can be assisted by appropriate decision-support systems or, in the case of novices, by a tutoring system. This too is shown

in figure 2, as well as the fact that the man-machine interface for the designer is normally completely different from those for the operator and the maintenance personnel. As mentioned above, the designers' decision-support systems may include an application model with knowledge and data about the technical process and its supervision and control system; an operator model will be provided with knowledge about the information search needs of the human operator as well as ergonomic and design procedural knowledge. The problem-solving strategies are mainly left with the designers because they determine the creative part of any design.

As is clear from figure 2, the knowledge contained in the designers' decision-support systems also needs to be generated. This is done in the knowledge acquisition process by the knowledge engineer and/or the domain experts who supply their technological and operational know-how for the conceptualization and implementation of the decision-support systems. Thus, the whole process of knowledge and information transfer as shown in figure 2 starts with the know-how of some experts and is carried through successive stages with their respective interactions by knowledge engineers, designers, and operators or maintenance personnel. Human errors that are made at any of the earlier stages may be propagated to later stages and, finally, may adversely influence the operation of the man-machine system. Reason [20] pointed out, for example, that the human errors of designers can sometimes be compensated for by the human operators but may also be the main contributing factor to turning a certain critical situation into a catastrophe. Regulations with product liability are more and more concerned with these aspects. Errors in early stages may eventually have severe consequences that call for careful avoidance and correction strategies as well as for training towards responsibility.

3. Knowledge-based information access by means of simulation and self-learning tools

3.1 Training Supervision and Control Tasks with Simulated Man-Machine Systems

Simulators of cars, trucks, aircraft, ships, power plants, chemical plants, and other technical processes are valuable tools for research and development as well as for training. They have a long tradition in aeronautics and astronautics, but nowadays are more often used in other application domains. The appropriate simulation fidelity is an important technical, psychological, and economic issue. Often, part-task simulators are sufficient, particularly for research. The simulation fidelity needs to be higher when professionals are to be trained in how to deal with difficult task situations. On the other hand, cheap simulators would be sufficient for less difficult tasks such as driving a car. A new technology for such inexpensive simulators for regular refresher training of drivers is needed, in my opinion, as one countermeasure to the far too many traffic accidents.

Simulated man-machine systems will be a technology that goes beyond the use of simulators. Here, the human operator's behaviour in supervision and control tasks is also simulated. This requires fairly accurate human performance models as well as models of mental workload. As Stassen et al. [29] summarized, such models are available for lower cognitive levels of human behaviour such as those required in manual control, failure detection, and monitoring. The use of these models in closed loops with the technical system leads to completely simulated man-machine systems. They can demonstrate in real time to any one interested how good or bad human interaction with a specific technical system may be. For training purposes, play-back capabilities for repeating any situation of interest, human interaction facilities with the possibility of comparing the trainee's with the ideal or bad simulated behaviour and performance, and explanations in separate text and graphics windows are necessary. Particularly with explanation facilities, such a simulated man-machine system becomes a tutoring system or self-learning tool for the training of supervision and control tasks for specific technical systems.

The three cognitive levels of human behaviour suggested by Rasmussen [19], namely skill-based, rule-

based, and knowledge-based behaviour, also have to be addressed appropriately during any training process. As Sheridan [25] proposed, computer aiding has to supply different support and needs different forms of interaction at these three levels. Demonstrations seem to be appropriate at the lowest level, whereas rules and advice are called for respectively at the two higher levels. A simple example may illustrate this. We assume a simulated man-machine system for training in car-driving tasks and select a typical driving situation on a motorway. This situation may be characterized by driving into and through a construction zone with narrower lane width and dense oncoming traffic. The demonstrations may show the outside view in real time for different selected speeds and may exemplify certain critical situations or even accidents. Rules for explaining the reasons behind the speed limits and the behavioural choices in critical situations may be shown in a separate window on the computer screen. This needs to be visible when observing the simulated outside view on the same colour graphics screen but shall not impair the main driving task. The explanations may be further supported by additional demonstrations. Only after the online demonstrations are terminated is the knowledge-based advice given. The human operator can take as much time as needed to interrogate the computer support in an interactive dialogue fashion. In this way, knowledge-based behaviour can be trained and, thus, through training, becomes rule-based behaviour.

Time pressure in the latter training phase and, generally, on the knowledge-based behavioural level is dangerous because it can even lead the human operator to fall back on the skill-based behavioural level with, then, a high risk of human errors [4]. The very last phase of the Chernobyl nuclear power plant accident can be explained by the choice under dramatic time pressure of the wrong skill-based behaviour instead of the necessary knowledge-based behaviour [16]. It may even be possible to demonstrate such human errors online in the simulation by freezing certain situations and by giving additional explanations for the wrong behaviour and for the causes behind it.

3.2 Self-learning Tools for Problem-solving Tasks

Not only supervision and control tasks but also the higher cognitive problem-solving tasks need to be trained appropriately. Unfortunately, our research results, particularly with respect to modelling problem-solving tasks, are not as well developed as our knowledge about control tasks [15]. It is even arguable whether it will ever be possible to model higher cognitive human functioning. Human creativity is a major ingredient in these functions and is mainly responsible for keeping the human being in the man-machine system. Planning tasks have not as yet been modelled sufficiently. Some models exist for human fault diagnosis tasks [23]. The more important research results contribute evaluations and concepts for experimental fault-diagnosis situations. Also, knowledge-based decision-support systems as computer aids for fault diagnosis were developed, as mentioned above (see also Johannsen and Alty [14]; Tzafestas [33]).

The idea here is to use and to integrate concepts, experimental results, models, and computer support systems for developing tools that allow self-learning and the information transfer of problem-solving tasks. The combination of such tools with the on-line simulation tools, as described in the preceding subsection, may further enhance the quality of the training system. It must be possible for human beings anywhere in the world to sit by themselves in a silent place in order to learn or just to understand basically how a particular technical system can be managed and operated, and how problems with this system can be solved once they occur. A reasonably large personal computer should be sufficient for such self-learning and information transfer purposes. Only the recent hardware revolution makes it feasible to supply enough computer power for such new training endeavours, even in geographically very remote places and in fairly limited economic situations. In the latter cases, access to the computer tools has to be organized for sharing their use in a way similar to that of using public library facilities.

Two off-line advisory systems for training maintenance personnel in fault-diagnosis capabilities will be

described here as existing examples for self-learning tools in problem-solving tasks. These two systems are FAULT (Framework for Aiding the Understanding of Logical Trouble-shooting), developed by Rouse and Hunt [23] and their colleagues over several years, and ADVISOR (Advanced Video Instructor), developed by Tanaka and others [31].

The original idea of FAULT was to investigate whether generalizable capabilities for fault diagnosis exist in human beings. Therefore, an early experiment was designed with the very abstract task of diagnosing a single fault in a complex network of nodes. In a second, more realistic example, the faulty components had to be identified in an electrical network with AND and OR gates. The connections between the components also included feedbacks. Both examples are suitable for training human operators in fairly general, context-free skills. With the FAULT system, a series of further experiments was performed that were context-specific, as in real-life tasks. The chosen networks were now schematics of car, aircraft, and ship engines with their main subsystems and components. The human subjects started the fault diagnosis with rather general symptoms (e.g. the engine will not start). Then they had to check gauges, ask for information about specific components, make observations, or remove components for testing. The symptom, the status of all available gauges, and the selected actions with their costs were displayed in different windows on the computer screen. Several forms of computer aiding based on models of human problem solving were used to assist the maintenance personnel in their troubleshooting tasks. The results of the experiments showed that human problem solving, which depends on how well the human operators understand the problems, is not optimal; see Rouse and Hunt [23]. There seems to be a trend towards context-dominated problem-solving behaviour. This is, however, not completely context-specific, as can be seen from human beings' abilities to make transitions into unfamiliar problems and to cope with ill-defined and ambiguous situations.

The recognized human cognitive limitations in problem-solving tasks can be overcome by computer-aiding systems based on some problem-solving performance models. Simpler computer aids may just be structure-oriented bookkeeping tools. In FAULT, it was shown that the bookkeeping methods consistently improved human performance, even after later transfer to unaided problem solving. FAULT was also used as a self-learning tool for maintenance personnel of ship engines. Like a tutor, the tool guided the human subjects through different knowledge-acquisition stages and problem-solving phases. Nowadays, similar tools are used for individual self-learning and for quick prescribed testing of the required status of knowledge at freely selected assessment times in airlines. These tools supplement the use of aircraft simulators in pilot training.

The ADVISOR system is another learning environment for maintenance [31]. It was developed jointly by the Tokyo Electric Power Corporation and Mitsubishi Electric Corporation. An interface-centred design approach was chosen, whereby multimedia techniques were also used. The system has some pedagogical interfaces to enhance the understanding of novices and to help them manage troubles and make appropriate guesses. Useful information and suggestions are provided in a format best adapted to the current understanding of the human subject, although the system does not provide a perfect model of human problem-solving performance. A prototype was developed for the maintenance of gas insulated switch gears in the power industries.

ADVISOR is implemented on a workstation, a personal computer, a videodisc, and a TV display. A real TV picture of the interesting views on and into the equipment in the maintenance situation is shown on the TV display with superimposed text windows for explanations and touch-sensitive virtual keys for interrogations. On the neighbouring colour graphics display of the workstation, learning from examples can be supported by explaining what the cause-consequence structures for a number of alarms look like in a multiple fault situation. Thus, the novice can learn the principles behind the examples. Also, the pedagogical interfaces can be shown with several windows on the display of the workstation as supports for recognizing the current status in the whole learning space as well as the significance of each step and

the intention behind it in the maintenance sequence. It is not known to this author whether the evaluation of the ADVISOR system was terminated, and what kind of results were achieved.

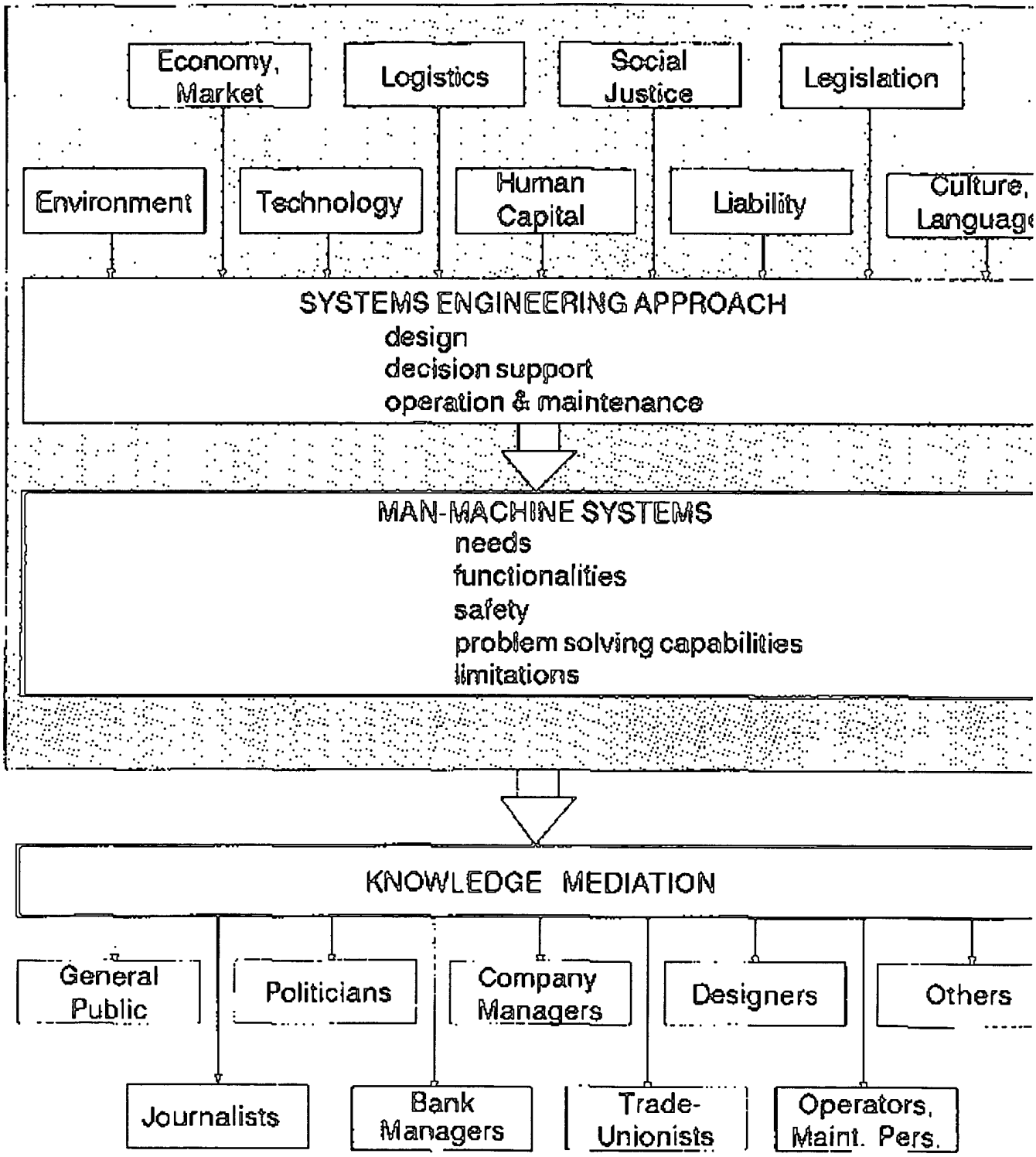
3.3 Self-learning Tools for Understanding Man-Machine Systems Engineering

Any man-machine system is a part or subset of a larger system with broader boundaries in the systems engineering sense. This has already been shown in figure 2 with the relationships between knowledge engineering, designing, operation, and maintenance; several man-machine systems are involved in this case. Nowadays, even broader contexts and perspectives need to be understood by different human agents dealing with man-machine systems; these include political decision makers, managers, designers. or operators. Different levels of understanding in different contexts are required. For example, environmental and economic issues, matters of legislation and liability, dependencies within a logistics network and of market developments, and many more technical and non-technical influences are to be considered in a real-life systems engineering approach towards decision support, design, and operation (see figure 3).

If knowledge about the needs and the functions of safe systems operation and careful problem solving in man-machine systems is better understood all over the world, then people will probably be more concerned about the selection and the proper use of many technical systems in their societies. The current challenges of technology transfer into developing countries and of conversion with risky systems in the industrialized countries, as mentioned already in the introductory section of this paper, may be better and more rapidly understood; possibly more competent opinions might be expressed if self-learning and information transfer tools were already available. Certainly a particularly strong need for such tools exists among high-level decision makers and public opinion moderators, namely among politicians, leaders of big and medium-sized companies and banks, and journalists (see figure 3). Their knowledge is often too limited and their time to learn something new very restricted, but they nevertheless have to make decisions quickly and as correctly as possible or to comment on actual events almost immediately. The suggested computerized tools for self-learning and information transfer will certainly complement libraries and more traditional information retrieval systems.

In a way similar to that in the prototypes mentioned in the preceding sub section, namely FAULT and ADVISOR, self-learning tools for understanding the broader issues of human interaction with technical systems in a societal context have to draw on a combination of decision-support systems, appropriate multimedia presentation and dialogue techniques in advanced man-machine interfaces, and explanation and justification facilities. The design approach for such tools has to start from requirements and cognitive task analyses that lead to the different decision-support functions needed for different types of later users of the tools. The explanation and justification facilities as well as the advanced man-machine interfaces have to be adapted to different information transfer and learning needs that are to be satisfied by the different decision-support systems.

Figure 3 Understanding man-machine systems engineering



3.4 Cultural Aspects of Using Simulation and Self-learning Tools

Simulation and self-learning tools, as mentioned in subsections 3.1 through 3.3, have to be used in free societies by different kinds of people with different kinds of education, different cognitive abilities for understanding systems, functions and context, and different kinds of responsibilities. Thus, one may say that different cultural patterns for approaching problems and interacting with socio-technical systems exist even within one particular society. Sometimes the differences between two distinct views of the

same system are cultivated unnecessarily, as often occurs with the distinction Snow [28] showed between the two cultures of science, namely one for the human and the social sciences and one for the natural and the engineering sciences. Bridging the gaps between all kinds of possible views seems to be more and more important for understanding our world and for contributing to a peaceful future.

These gaps between cultures can be much larger when we look at the differences between societies that developed quite independently from each other over many centuries. Take the Japanese and the German cultures as examples that show a completely distinct dimension of cultural differences from those within either of these two societies. Sheridan et al. [27] dealt with many facets of these cultural apects.

Although the gaps between different cultures, individual as well as societal, became much smaller through the influence of many technologies, particularly the information technologies, many unique traditions and language barriers remain. They have to be accepted and even preserved with patience, goodwill, and historical sense. However, they need also to be overcome mentally in order to allow worldwide cooperation as well as exchange of ideas and products in a successful and mutually rewarding manner. The ideas and technologies of one culture have to be appropriately adapted to another culture when a high degree of user acceptability shall be reached. This requires sensitive tutoring for systems designers in the delivering culture as well as concerned training for end-users in the receiving culture. Thus, two types of simulation and self-learning tools may well be suitable. For the designers, one type can aid the understanding of other cultures. For training purposes, the other type can support understanding of the culturally adapted technology. Multilingual explanation facilities seem to be important aids where appropriate and where necessary to enhancing understanding for the tools that have to consider cultural differences. The use of voice output and input within a multimedia environment may even allow illiterates to get acquainted with new technical systems by means of the suggested tools.

The need for investigating and for considering cultural aspects in the design and use of technologies, in particular automation and information technologies, have only recently been recognized, also by at least some engineers and computer scientists. In the International Federation of Automatic Control (IFAC), a Working Group on Cultural Aspects of Automation was formed in 1990, for example. They organized their first workshop in October 1991 [7].

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4. Needs for future research and socio-technical development

The overall objectives mentioned in the introduction of this paper for using computer-aided information transfer and self-learning tools can only be achieved with further research combined with particular socio-technical developments. Future research is needed in the areas of human performance modelling and problem solving, goal and knowledge structures, cognitive limitations, knowledge acquisition, and all their contributions to the design of more cooperative interactive decision-support systems. More research is required in the development of knowledge-based explanation and justification facilities as well as in advanced man-machine interfaces with multimedia presentation and dialogue techniques. Information retrieval and tutoring techniques also have to be further developed for the particular needs of these tools.

In addition to the future research requirements just mentioned, the socio-technical development of simulated man-machine systems and self-learning tools has to be fostered for many application domains. An integrated multidisciplinary approach towards development and training for expanding information access seems to be mandatory. Several specialized companies as well as research and development centres with an existing or planned international operational basis have to take up the new challenges of information dissemination in a more systematic way. Then we can hope that a sufficient number of people all over the world will appropriately understand human interactions with all kinds of technical systems in order to contribute through responsible decisions to the future and peace of mankind.

Of course, the most elementary needs of food, shelter, and health have to be satisfied first. This has yet to be accomplished for more than 40 per cent of the world population, due in particular to the lack of environmental conservation according to a very recent report of the World Health Organization. Only after an acceptable minimum standard of living is reached will people be concerned with seeking better information supply. However, even for solving these elementary problems, a lot of information support is required, for example in order to enforce environmental conservation. Thus, we face a vicious circle. To get out of this is also very much a matter of politics, economics, and world trade. But nothing can be accomplished without more proper use of science and technology.

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Abstract
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2. Human-centred design
3. Applications
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5. Conclusions
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William B. Rouse

Abstract

The design of information systems is considered in terms of the viability, acceptability, and validity of the information support provided. These issues are discussed in the context of several examples, including systems for bibliographic information retrieval, aircraft operations, maintenance information, sales transaction support, and design information. A variety of "lessons learned" that illustrate the impact of adopting a human-centred approach to designing information systems is summarized.

1. Introduction

Information is an essential ingredient in much that we do. We spend much time gathering, refining, and interpreting information. This process of digesting information has become increasingly complex as the store of information has become larger and more diverse.

The size of the information store makes it difficult to consume all relevant information. The increasing diversity of information sources, forms, and languages makes it difficult to identify and interpret all relevant information. Often indigestion and sometimes "information poisoning" result.

Information technology appears to provide the means whereby these problems can be overcome. Hypermedia, multimedia, natural language processing, expert systems, and CD-ROM are notable examples. Numerous commentators over the past 40 years projected that technologies such as these would soon help us to deal with the information explosion. Each of these commentators has, at best, been a bit too optimistic.

One could argue that the proclamations of success were premature because the cost and/or power of computer technology, as well as related technologies, did not evolve as quickly as anticipated. While this may be true, I believe that more subtle problems have hindered progress. Put simply, enabling technologies such as those noted above may be necessary, but they are not sufficient for success.

To support this assertion, consider the following two examples. In the late 1970s and early 1980s, we undertook an effort to put hard-copy procedural information on-line. It seemed intuitively obvious that problems associated with the growing size and number of technical manuals could be lessened, or perhaps eliminated by moving to computer-based information systems.

Two studies were performed in the context of aircraft operations manuals [5, 6]. Of particular interest here is the first study, where one condition involved putting on the computer display the exact same

information, in the same format, as in the hard-copy manuals. Experimental results for this condition indicated the computer-based system was substantially inferior to the hard-copy presentation.

The problems appeared to be due to the inherently limited screen size and the distinct possibility of getting lost in the display hierarchy. Fortunately, means were devised for alleviating these problems and a derivative of the display system discussed by Rouse, Rouse, and Hammer [6] is being used in the Boeing 777 aircraft. Nevertheless, the "lesson learned" is clear- simply putting information on a computer does not necessarily make it more useful than presenting it in more traditional ways.

The second example concerns an effort in the mid-1980s to develop intelligent bibliographic information retrieval systems, primarily for use by engineers and scientists. Five studies were performed to understand how various computer aiding schemes affected users' abilities to retrieve information of value. The results of this series of studies are reviewed by Morehead and Rouse [3].

Three of the studies considered the impact of providing links among articles based on reference lists. As we expected, such links helped considerably. This led us to add further links based on citations of articles. In this way, an article was linked to both its ancestors and its descendants.

Much to our surprise, the citation links substantially degraded users' performance. Users tended to wander down citation paths long after they ceased to be productive. We modified the system to display the productivity metric of articles selected divided by articles viewed. In this way, the decrease in productivity of citation paths became evident to users and they abandoned citation paths much sooner. The "lesson learned" here is also clear - providing more links among information elements is not necessarily beneficial and may be detrimental.

Thus, the intuitively obvious benefits of enabling information technologies are not always realized. The straightforward reason is that intuition is not always right, as numerous lottery customers will attest. Rather than betting on technologies, users would be much better served if we first focused on the benefits sought, and then considered alternative means of providing these benefits.

2. Human-centred design

The types of problems noted earlier can be avoided, and the potential of enabling information technologies can be realized, by adopting a human-centred approach to designing information systems. Human-centred design is a process of assuring that the concerns, values, and perceptions of all stakeholders in a design effort are considered and balanced [X].

Stakeholders include users, customers, maintainers, investors, and so on. Further, the designers of information systems are stakeholders in these systems. While this paper necessarily focuses on users, were we to discuss the design, development, implementation, and servicing of an actual information system, we would consider all of the stakeholders.

Human-centred design can be viewed as a process for addressing and resolving the seven issues listed in figure 1. Four of these issues (i.e., evaluation, demonstration, verification, and testing) are well known to designers of information systems and are usually addressed in a reasonable manner. These four issues are not discussed within the confines of this paper. Interested readers will find a comprehensive treatment of these issues in Rouse [8].

The top three issues in the figure (i.e., viability, acceptability, and validity) are seldom addressed with sufficient rigour by designers of information systems. Human-centred design involves pursuing all of

the issues in figure 1, starting at the top. Thus, the first question asked is "What matters?" while the last question asked is "Does it run?"

Rouse [8] discusses a four-phase methodology, as well as associated methods and tools, for pursuing the seven issues in figure 1. In this paper, discussion focuses on elaborating the nature of viability, acceptability, and validity. The use of these constructs is subsequently illustrated in the context of a few applications.

Viability is concerned with benefits and costs. Contrary to the apparent beliefs of many designers of information systems, the primary benefits to users seldom include having the opportunity to use an information system. Users typically use an information system to make better-informed decisions, solve problems, order products and services, save time, and so on.

Costs may include access charges; however, such costs are often paid by third parties. For most users, costs include the difficulty and time involved in learning to use and in using the system, as well as the difficulty and time associated with using the outputs of the system. Thus, for example, one of the costs of using conventional computer-based information retrieval systems is the difficulty and time of wading through the hundreds or thousands of abstracts obtained, as well as locating and obtaining source documents.

Viability(ρ) Are the Benefits of System Use Sufficiently Greater than its Costs?

Acceptability(ρ) Do Organizations/lndividuals Use the System?

Validity (ρ) Does the System Solve the Problem?

Evaluation (ρ) Does the System Meet Requirements?

Demonstration (ρ) How Do Observers React to System?

Verification (ρ) Is the System Put Together as Planned?

Testing (ρ) Does the System Run, Compute, Etc.?

Figure 1 Human-centred design issues

Acceptability concerns the extent to which a way of doing things fits in with individual and organizational preferences and constraints. For instance, the hardware and software of an information system should be compatible with other hardware and software employed by users and their organizations. A more subtle need is for usage procedures for the information system to be compatible with usage procedures for other systems used by the same set of users. An example of preference-related acceptability concerns would-be users' desires for colourgraphic displays despite the fact that monochromatic alphanumeric displays would be less expensive and provide a valid means to meeting information needs.

Validity focuses on whether or not an information system solves the users' information-seeking problems. It is quite possible for a system to meet requirements - that is, pass evaluation with flying colours - but not provide valid support. For example, an information system might rapidly retrieve and display masses of information, much of which is irrelevant, the remainder of which is only marginally

understandable by the class of users for which the system was designed. While one could blame this on the quality of the databases and argue that the information system satisfies its technical requirements, it is nevertheless a fact that the system does not provide a valid solution to users' problems. One might attempt to resolve this problem by adding artificially intelligent functionality that reads and translates all of the information retrieved to assure that what users get is relevant and understandable. This would not necessarily lessen validity problems if users were skeptical of the computer's ability to perform such filtering and translation.

Note that the discussions of human-centred design in this section have only paid passing attention to display formats? dialogue structures, and so on. While these issues are important, they are nor synonymous with the user-system interface within the human-centred design framework. Within this framework, the interface is "deeper" than the displays and keyboard. The interface includes all functionality whose goals are to enhance human abilities, overcome human limitations, and foster user acceptance [8].

Therefore, within human-centred design, one does not design an information system and then "add" a user-system interface. Instead, one begins with the user in terms of benefits, costs, etc., and progressively deepens the design. At some point, one translates the means to providing benefits into particular enabling technologies. Typically, the design of displays and input devices naturally evolves in this progression. In this way, human-centred design not only results in systems that are usable- it also produces systems that are useful.

3. Applications

In this section, three example applications are discussed: (1) maintenance information systems; (2) sales transaction systems; and (3) design information systems. The purpose of these illustrations is to show how human-centred design influences the nature of the products and systems that result.

3.1 Maintenance Information Systems

The application concerned the problem of transforming large, blueprint-size hard copy, often called C size, to small, computer-display-size images [2]. The context of interest was helicopter maintenance.

A very important element of human-centred design is initial emphasis on defining the true nature of the problem to be solved. From the point of view of the humans involved in this context, the problem of interest was helicopter maintenance, not reading blueprints. Thus, in terms of validity the primary concern was providing information to support maintenance activities rather than finding a way to access blueprints on a small display.

This realization led us to focus on the tasks to be done rather than on the nature of blueprints. It became clear that information is used in different ways depending on the nature of the task, i.e., problem solving vs. procedure execution. This conclusion led us to adopt Rasmussen's abstraction-aggregation hierarchy [4] as a means of organizing maintenance information.

The abstraction dimension included physical form, physical function, and generalized function depicted in terms of location diagrams, schematics, and block diagrams, respectively. The aggregation dimension included assembly, subsystem, and system-level representations. As a consequence of this approach to organizing information, it was no longer necessary to have large displays.

This system concept was evaluated in a series of five experiments. It was determined that the nature of

the displays affected maintainers' activities. They performed at least as well using the new displays and overwhelmingly preferred the new displays. Further, it was determined that creation and updating of the display database would be easier with the new approach. Thus, both acceptability and viability were improved.

3.2 Sales Transaction Support

Computer-mediated sales are an increasingly prevalent approach to selling in retail stores, banks, airlines, and many other domains. Perhaps not surprisingly, there has been considerable interest in improving the user-system interface of such systems. Of particular concern, because of the high turnover among people performing such jobs, has been decreasing or possibly eliminating the need for any extensive training in the use of these systems.

We undertook two efforts in this area, one in the domain of retail sales and the other in passenger reservation systems. In both cases, we were asked to improve the usability of these systems by focusing on the user-system interface. We employed the human-centred design methodology to pursue these efforts.

In both cases, we focused initially on viability, acceptability, and validity for a period of 4-6 weeks. We discovered that usability problems, while important, were by no means the predominant concern. The benefit sought in both cases was increased sales and the cost was the time required to make sales.

It would have been quite possible to solve usability problems without enhancing viability - increasing benefits and/or decreasing costs. Focusing solely on usability would have probably increased individual user acceptance but not necessarily organizational acceptance. Finally, solving usability problems alone might have met requirements, but would not have been a valid solution to the right problem.

For both efforts, the initial focus on viability, acceptability, and validity led to an emphasis on sales support rather than solely on improved operability of computer terminals. While usability and the user-system interface still received much attention, it was given in the context of supporting the tasks that really mattered. The result was system designs that were substantially different from those originally envisioned.

3.3 Design Information Systems

The application under design information systems focused on access to and utilization of science and technology information in the context of designing aerospace systems. The motivation for this effort included a long-term interest in the value of information [7, 11], as well as a practical need to develop design information systems.

In keeping with the human-centred approach to design, we began by focusing on viability, acceptability, and validity. These issues were pursued using questionnaires, interviews, and observational techniques involving a large number of designers [9]. We found that very little science and technology information is accessed by formal means.

Why don't designers take advantage of science and technology information? One answer is that they perceive little benefit and great cost in accessing this type of information. They attach no benefit to using the information system per se.

They are concerned with making informed design decisions. They become informed by asking other

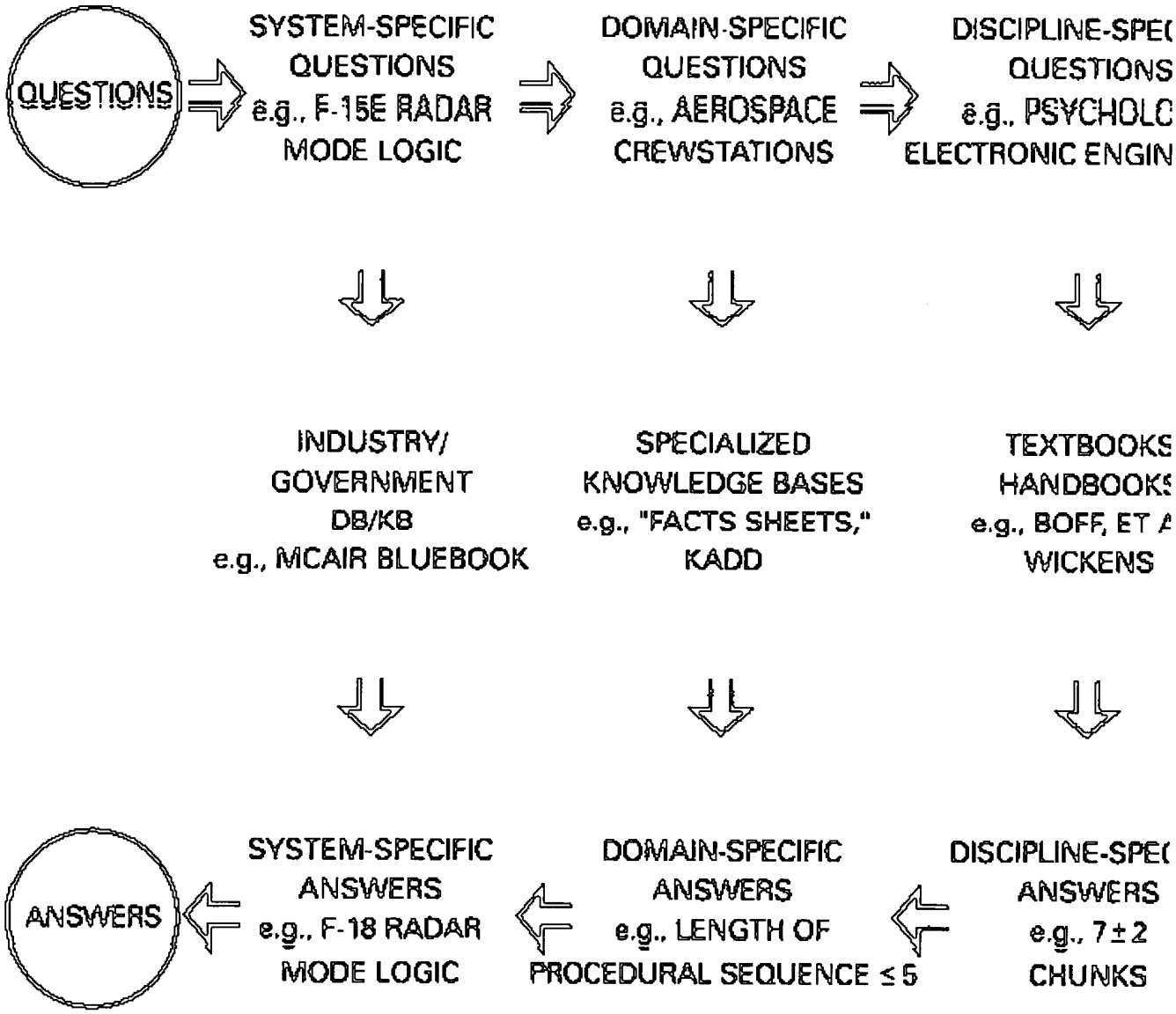
people in their organization, a conclusion also reached by Allen [1]. Why do they rely on subjective opinions rather than the "hard" objective information provided by science and technology? A primary reason is that they find published research results to be applicable in general but not to their specific problems in particular. They want contextually based answers to their questions rather than generic simplifications. In other words, they question the validity of available science and technology information.

There are also acceptability problems. Almost all science and technology information is created, written, and published for consumption by scientists and technologists. Designers seldom have the specialized expertise, or the patience, to penetrate this information. They find the context and format of presentation totally unacceptable.

The essense of the designer's dilemma is depicted in figure 2. Each transformation in this diagram requires time and effort. Both time and effort increase as one moves to the right in this diagram. It is easy to see why a designer would not want 1,000 abstracts of research articles on human memory to answer a question concerning usability of radar modes. The cost of answering questions in this way far outweighs the benefits.

The above conclusions concerning designers' perceptions of viability, acceptability, and validity caused us to focus on designers' tasks and information needs rather than on the nature of science and technology information. Thus, rather than focusing on how to get designers to access and utilize science and technology information, we looked at the information requirements to support design decision-making. Such requirements should drive the way in which science and technology information is created, organized, formatted, and accessed if this information is intended to support design.

Figure 2 Alternative transformations in answering questions



After considering alternative representations, we concluded that information seeking in design could be represented as a process of asking questions and pursuing answers in the context of a "design space" including a set of archetypical tasks focused on attributes of the design artifact and characterized in terms of abstraction and aggregation [10]. Typical scenarios or trajectories in the design space were studied to determine information requirements in particular and support requirements in general. Using a structured analysis and design methodology [8] led to identification of hundreds of requirements and an appropriate conceptual architecture that would satisfy these requirements.

4. Lessons learned

The human-centred design issues of viability, acceptability, and validity have been discussed in the context of several examples, including systems for bibliographic information retrieval, aircraft operations, maintenance information, sales transaction support, and design information. In this section, the lessons learned from these efforts are summarized.

First and foremost, it is essential to recognize that information access and utilization are seldom ends in

themselves. The benefit sought is successful task performance, not information seeking. Thus, primary tasks of interest do not include operating an information system.

Regarding primary tasks, the information requirements associated with these tasks would dictate information system design. The existing organization and format of information should not, to the extent possible, constrain the nature of an information system. It should also be noted that the ways in which information requirements are satisfied are likely to vary with tasks, despite the fact that the same information content may be required for two or more tasks.

Simply putting information on a computer display is not necessarily better, and may be worse, than using other media, unless appropriate aiding is provided to enable using the information in new ways. Similarly, additional information is not necessarily better, and may be worse, without appropriate aiding to enable using the new information.

People tend to interpret the validity of information in a very context-specific manner relative to their needs at the moment. People are also more likely to find information acceptable if its format and content make it easy to understand and interpret.

Finally, by focusing on the issues of viability, acceptability, and validity within the human-centred design framework, one is much more likely to solve the right problem and solve it in an acceptable way. The result is information systems that are both usable and useful.

5. Conclusions

The information explosion continues unabated. The promise of information technology has long been heralded as a means of containing, and perhaps counteracting, this explosion. This paper has argued and illustrated with many examples that the problem is not amenable to technology panaceas. Instead, success is much more likely if the concepts, principles, methods, and tools of human-centred design are used to determine contextually relevant information requirements, as well as synthesize support systems that satisfy these requirements.

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Designing interactive systems based on cognitive theories of human information processing

Abstract
Introduction
1. Hypermedia systems
2. User-oriented and task-driven system design
3. SEPIA: A cooperative hypermedia authoring environment
4. Conclusion
References

Norbert A. Streitz

Abstract

Hypertext and hypermedia are introduced as a solution to the question of how best to produce and provide the information now required by all kinds of users. The new generation of information systems must be user-oriented and task-driven, and their design should rely on knowledge about the manner in which the human mind processes information. Extensive reference is made to the cooperative hypermedia authoring environment SEPIA.

Introduction

I start from the assumption that the world of today - and, certainly, that of tomorrow - depends more and more on the availability of the right information at the right time and in an appropriate quantity and quality. Not judging in this context whether this development is good or bad, a question remains on how to produce this information and how to provide it to clients, students, teachers, engineers, readers, and users in general. My first claim is that hypermedia systems will offer a solution to this problem. They represent the beginning of the development of a new generation of information and publication systems.

It is my second claim that the development of these information systems has to follow the approach of user-oriented and task-driven system design. It is my third claim that the application of this approach has to rely heavily on knowledge about human information processing, i.e. cognitive theories. In summary, I claim the inherent capabilities of hypermedia systems will meet the requirements of cognitively adequate human-computer interfaces and the demands for task-driven provision of functionality needed to support a variety of work activities.

The goal of this contribution is to show for selected areas what is needed in order to live up to the expectations raised by the concept of hypertext and hypermedia. The paper is structured as follows: First, I introduce the concepts of hypertext and hypermedia. Second, I present five basic requirements for user-oriented and task-driven system design. Third, I describe the proposed research and development strategy in the context of the cooperative hypermedia authoring environment SEPIA. SEPIA is an example of how the design of an interactive system is heavily based on theories of human information processing, in this case on cognitive models of authoring hyperdocuments. SEPIA is part of the current research activities at the Integrated Publication and Information Systems Institute (IPSI) of the Gesellschaft für Mathematik und Datenverarbeitung (GMD) in Darmstadt, Germany.

1. Hypermedia systems

1.1 Basic Concepts

First, we need to distinguish between *hypertext* and *hypermedia*. In my usage, hypertext uses the structural aspects. This concept is based on the idea of a nonlinear organization of pieces of information ("nodes") that can be referenced and related to each other by "links" in an associative manner and constitute a network structure (directed graph including cycles). An essential feature of hypertext is the capability of having machine-supported links within and between documents. On the other hand, I use the term *hypermedia* if the nodes contain multimedia contents, e.g. sound, complex graphics, pictures, video, or animation. No doubt multimedia aspects will contribute to the attractiveness and dissemination of the innovative hypertext concept. But one has to note that multimedia provides only the technological basis, e.g. digitizing pictures and compressing them, showing video in a window, editing sound, etc. Currently, multimedia applications consist more or less of the presentation of a collection of multimedia content. What is lacking is structure, a concept of how to relate information elements to each other, how to use this information, which again has implications for the combination and presentation of information. But this is what hypermedia is all about.

I claim that hypermedia systems will provide qualitatively new means for producing, communicating, and comprehending knowledge and will radically change the conditions of the information society [26, 27]. Additional information will be provided as we go along. Since the expectations about the potential of hypermedia systems are very high, the role of hypermedia in a comprehensive information environment has to be clarified. In my opinion, expectations will not be met by relying solely on the concept of hypertext and hypermedia. Rather, these are the crystallization nucleus for the development of a new generation. They must be complemented by considering and integrating existing results and future achievements in the following areas:

- ergonomic design of human-computer interaction database management systems
- information retrieval
- knowledge-based components
- publication and high-quality layout systems
- telecommunication and computer networks

Current hypermedia systems are only a first demonstration of the elementary principles that raise our interest in what is still to come in the future. Since there is no space to discuss the deficits of existing systems and approaches, I refer to Conklin [4], Halasz [6, 7], Russell [2]], and Streitz [26, 27]. Much of the confusion about hypermedia is caused by people's attempts to define it as one application among others, as similar, e.g., to desktop publishing. From my perspective, hypermedia systems are technological examples of a set of basic but very powerful principles with a high potential for innovations that enable the definition and creation of new applications or value adding for existing applications.

1.2 Authoring versus Retrieval

Discussions about the implications of computer technology for the information society seem to address primarily problems of how to provide information (presentation, retrieval, filtering, etc.). While these are valid issues, at least an equally important aspect is largely neglected: a prerequisite for information retrieval and presentation - not only in hypermedia systems - is that this information must have been produced. Therefore, we have to provide tools for authoring and production. The quality of the next generation of hypermedia systems will depend on the extent and quality of support in authoring environments. Most of the hyperdocuments currently produced rely on the method of "turning (existing linear) text into hypertext." There may be value in turning existing paper or linear electronic documents into electronic hyperdocuments. But the results rarely show what an innovative hyperdocument could actually be like. Most of the existing tools for creating hypertexts are not well suited for this task. A review of existing guides shows that the issue of providing adequate conceptual support for authors of hyperdocuments has not been sufficiently addressed. There is another deficit in hypertext research with respect to writing. Current research is not really addressing the crucial problem that producing a non-linear document might require very different concepts of creating, revising, and composing documents and therefore different kinds of support. But it is my strong belief that the concepts of hypertext and hypermedia will only be convincing and successful if there are dedicated tools that correspond to the special characteristics inherent to the innovative potential of hyperdocuments.

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Projects:

ILSA. Independent LifeStyle Assistant. 2000-2003. Lead Architect. Develop an intelligent, adaptive home automation system with a sophisticated situation awareness and decision-making capabilities that reason over a diverse set of sensors, medical devices and "smart" appliances to enable elderly and infirm users to live and function safely at home. $5.2 M NIST program. Seven patents pending.

KIRM. Knowledge Integration and Resource Management. 2000. coPM/PI. Integrating information collected from many diverse knowledge sources and analytical techniques to create links between otherwise unconnected information. Uses machine learning techniques to extract relevant information from disparate sources, then structures and links the representation, providing a knowledge based to query for mixed-initiative decision support. Patent pending.

DETER. Detection of Events for Threat Evaluation and Recognition. 1999-2000. Automatic detection of suspicious behaviour for high-end security applications. Image understanding to identify and track moving objects, followed by machine learning to build models of suspicious and innocuous behaviours, which can be used to raise alarms for security personnel. Honeywell Technical Achievement Award. Patent pending.

LAMP. Learning Alarm Management Project. 1999-2000. PM/PI. Machine learning to correlate and filter alarm showers from oil refineries. LAMP examines the plant history and logical configuration to dynamically consolidate alarms into groups, improving operator performance by effectively communicating plant states implied by alarms.

D2K. Documents To Knowledge. 1999-2000. PM/PI. Machine learning to extract patterns in natural language for use in categorizing statements in legacy documents. Developed a knowledge-based distance metric, based on natural language processing techniques, which compares the similarity of English sentences. Patent pending.

TMR. Tactical Mobile Robots (with Georgia Institute of Technology). 1998-2000. PM/PI. Analysis of the hard

real-time performance of composable robot behaviours. Allows users to dynamically build configurations of robot behaviours, and then provides an analysis of the feasibility of the configuration in terms of hardware capabilities and real-time schedulability.

TMR (II). Tactical Mobile Robots (with Carnegie Mellon University). 1998-1999. Constraint-based planner for teams of cooperating agents in the domain of tactical robotic urban reconnaissance. Evaluates user instructions for feasibility and correctness, and expands and refines them to produce fully executable plans that intelligently manage limited resources and coordinate multiple agents.

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Supervisor: Dr. Stan Matwin.
Developed and tested a machine learning package for negotiation support based on genetic algorithms.

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1992-1998:	Graduate Fellowship, Carnegie Mellon University.
1994-1996:	Postgraduate Scholarship, Canadian Space Agency.
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2000: Paper reviewing: IEEE Trans. on Knowledge and Data Engineering, IEEE Control Systems Magazine, Agents 2000, AAAI 2000
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Evidence Sets: Modeling Subjective Categories

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Abstract: Zadeh's Fuzzy Sets are extended with the Dempster-Shafer Theory of Evidence into a new mathematical structure called Evidence Sets, which can capture more efficiently all recognized forms of uncertainty in a formalism that explicitly models the subjective context dependencies of linguistic categories. A belief-based theory of Approximate Reasoning is proposed for these structures. Evidence sets are then used in the development of a relational database architecture useful for the data mining of information stored in several networked databases. This useful data mining application establishes an Artificial Intelligence model of Cognitive Categorization with a hybrid architecture that possesses both connectionist and symbolic attributes.

INDEX TERMS: Fuzzy Sets, Dempster-Shafer Theory of Evidence, Interval Valued Fuzzy Sets, Uncertainty, Cognitive Categorization, Constructivism, Relational Databases, Distributed Memory, Information Technology; Information Retrieval; Adaptive Collaborative Systems; Knowledge Management.

1. Cognitive Categorization

Categories are bundles of concepts somehow associated in some context. Cognitive agents survive in a particular environment by categorizing their perceptions, feelings, thoughts, and language. The evolutionary value of categorization skills is related to the ability cognitive agents have to discriminate and group relevant events in their environments which may demand reactions necessary for their survival. If organisms can map a

potentially infinite number of events in their environments to a relatively small number of categories of events demanding a particular reaction, and if this mapping allows them to respond effectively to relevant aspects of their environment, then only a finite amount of memory is necessary for an organism to respond to a potentially infinitely complex environment.

Thus, knowledge is equated with the survival of organisms capable of using memories of categorization processes to choose suitable actions in different environmental contexts. It is not the purpose here to dwell into the interesting issues of evolutionary epistemology [Campbell, 1974; Lorenz, 1971], I merely want to start this discussion by positioning categorization as a very important aspect of the survival of memory empowered organisms. Understanding categorization as an evolutionary (control) relationship between a memory empowered organism and its environment, implies the understanding of knowledge not as a completely observer independent mapping of real world categories into an organism's memory, but rather as the organism's, embodied, thus subjective, own construction of relevant - to its survival - distinctions in its environment. These ideas have been developed in more detail in [Rocha, 1997a, 1997b; Henry and Rocha, 1996] where an epistemological position named *Evolutionary Constructivism* is outlined and defended.

Since effective categorization of a potentially infinitely complex environment allows an organism to survive with limited amounts of memory, we can also see a connection between uncertainty and categorization. Klir [1991] has argued that the utilization of uncertainty is an important tool to tackle complexity. If the embodiment of an organism allows it to recognize (construct) relevant events in its environment, but if all the recognizable events are still too complex to grasp by a limited memory system, the establishment of one-to-many relations between tokens of these events and the events themselves, might be advantageous for its survival. In other words, the introduction of uncertainty may be a necessity for systems with a limited amount of memory, in order to maintain relevant information about their environments. Thus, it is considered important for models of human categories to capture all recognized forms of uncertainty. In the following, I address the historical relation between set theory and our understanding of categories; in particular, I discuss what kind of extensions we need to impose on fuzzy sets so that they may become better tools in the modeling of subjective, uncertain, cognitive categories.

2. Models of Cognitive Categorization

It is important to separate the idea of a model of cognitive categorization and a model of a category. Though obviously dependent on one another, categories are included in more general models of cognitive categorization and knowledge representation. Agreeing on what the structure of a category might be, is far from agreeing on what the structure and workings of cognitive categorization models should be. It is also a simpler problem. Though, undoubtedly, the specific model of knowledge organization selected will dictate some of the properties of categories, the particular structure chosen to represent categories in such models does not have to offer an explanation for knowledge organization. All that is asked of a good category representation, is that it may allow the larger imbedding model of knowledge representation to function. For instance, if we use sets to represent categories, our models of knowledge representation may use set theory connectives and/or they may use more complicated sets of mappings or even introduce connectionist machines to produce the sets [Clark, 1993]. Thus, evaluating sets as prospective representations of

categories should be done by analyzing the kinds of limitations they *necessarily* impose on *any* kind of model, and not simply models circumscribed to basic set-theoretic operations.

2.1 The Classical View

The classical theory of categorization defines categories as containers of elements with common properties. Naturally, the classic, crisp, set structure was ideal to represent such containers: an element of a universe of observation can be either inside or outside a certain category, if it has or has not, respectively, the defining properties of the category in question. Further, all elements have equal standing in the category: there are no preferred representatives of a category - all or nothing membership.

One other characteristic of the classical view of categorization has to do with an observer independent epistemology: realism or objectivism. Cognitive categories were thought to represent objective distinctions in the real world; say, divisions between colors, between sounds, were all assumed to be characteristics of the real world independent from any beings doing the categorizing. Frequently, this objectivism is linked to the way classical categories are constructed on all-or-nothing sets of objects: "if categories are defined only by properties inherent in the members, then categories should be independent of the peculiarities of any beings doing the categorizing" [Lakoff, 1987, page 7]. I do not subscribe to this point of view; we can use classical categories both in realist or constructivist epistemologies. Even with classical, all-or-nothing, categories, the properties are not inherent in the members, there is always something or someone defining the necessary list of properties. The question is who or what is to establish the shared properties of a particular category. A model where these shared properties are regarded as observer dependent, that is, established in reference to the particular physiology and cognition of the agent doing the categorizing, is built under a constructivist epistemology. If on the other hand, these properties are considered to be the ultimate truth of the real world, then the aim is the definition of an objectivist model of reality.

Most modern theories of categorization include classical categories as a special case of a more complex scheme, which does not imply that some categories are objective and others are subjective. Thus, classical categories have to do with an all-or-nothing description of sets, based on a list of shared properties defined in some model. This external model is indeed built within an objectivist epistemology in the classical approach, but these two aspects of the classical theory of categorization are not necessarily dependent. The chosen structure of categories and the chosen model of knowledge representation/manipulation, which can be realist or constructivist, may be independent concerns when modeling cognitive categorization.

2.2 Prototype Theory and Fuzzy Sets

Rosch [1975, 1978] proposed a theory of category prototypes in which, basically, some elements are considered better representatives of a category than others. It was also shown that most categories cannot be defined by a mere listing of properties shared by all elements. Some approaches define this degree of representativeness as the distance to a salient example element of the category: a *prototype* [Medin and Schaffer, 1978]. More recently, prototypes have been accepted as abstract entities, and not necessarily a real element of the category [Smith and Medin, 1981]. An example would be the categorization of

eggs by Lorenz'[1981] geese, who seem to use an abstract prototype element based on such attributes as color, speckled pattern, shape, and size. It is easy to fool a goose with a wooden egg if the abstract characteristics of the prototype are emphasized.

Naturally, fuzzy sets became candidates for the simulation of prototype categories on two counts: (i) membership degrees could represent the degree of prototypicality of a concept regarding a particular category; (ii) a category could also be defined as the degree to which its elements observe a number of properties, in particular, these properties may represent relevant characteristics of the prototype. These two points are distinct. The first makes no claim whatsoever on the mechanisms of creation and manipulation of categories. It may be challenged, as I will do in the sequel, on the grounds that due to its simplicity, models using it must be extremely complicated. Nonetheless, it does offer the minimum requirement a category must observe: a group (set) of elements with varying degrees of representativeness of the category itself.

The second point goes beyond the definition of a category and enters the domain of modeling the creation of categories. As in the classic case, categories are seen as groups of elements observing a list of properties, the only difference is that elements are allowed to observe these properties to a degree. However, the so called radial categories [Lakoff, 1987] cannot be formed by a listing of properties shared by all its elements, even if to a degree. They refer to categories possessing a central subcategory core, defined by some coherent (to a model or context) listing of properties, plus some other elements which must be learned one by one once different contexts are introduced, but which are unpredictable from the core's context and its listing of shared properties. Thus, the second interpretation of fuzzy sets as categories leads fuzzy logic to a corner which renders it uninteresting to the modeling of cognitive categorization. Notice that Rosch herself made a distinction between the notion of category prototypes and the notion of knowledge representation:

> "Prototypes do not constitute any particular processing model for categories [...]. What the facts about prototypicality do contribute to processing notions is a constraint -- process models should not be inconsistent with the known facts about prototypes. [...] As with processing models, the facts about prototypes can only constrain, but do not determine, models of representation." [Rosch, 1978, pg. 40]

Since fuzzy sets, at least to a degree, can be included in realist or constructivist frameworks, its dismissal as good models of cognitive categories has to be made on different grounds. In the following I will maintain that fuzzy sets are unsatisfactory because they (i) lead to very complicated models, (ii) do not capture all forms of uncertainty necessary to model mental behavior, and (iii) leave all the considerations of a logic of subjective belief to the larger imbedding model, which makes them poor tools in evolutionary constructivist approaches. A formal extension based on evidence theory is proposed next.

2.3 Dynamic Categories

As Hampton [1992] and Clark [1993] discuss, the important question to ask at this point is "where do the prototypicality degrees come from?" Barsalou [1987] has shown how the prototypical judgments of categories are very unstable across contexts. He proposes that these judgements, and therefore the structure of categories, are constructed "on the hoof" from contextual subsets of information stored in long-term memory. The conclusion is that

such a wide variety of context-adapting categories cannot be stored in our brains, they are instead dynamic categories which are rarely, if ever, constructed twice by the same cognitive system. Categories may indeed have Rosch's graded prototypicality structure, but they are not stored as such, merely constructed "on the hoof" from some other form of information storage system.

> "Invariant representations of categories do not exist in human cognitive systems. Instead, invariant representations of categories are analytic fictions created by those who study them." [Barsalou, 1987 p. 114]

As Clark [1993] points out, since the evidence for graded categories is so strong, even in ad hoc categories such as "things that could fall on your head" or viewpoint-related categories, "it seems implausible to suppose that the gradations are built into some preexisting conceptual unit or prototype that has been simply extracted whole out of long-term memory." [Ibid, page 93] Thus, we should take the graded prototypical categories as representations of these highly transient, context-dependent knowledge arrangements, and not of models of information storage in the brain. In the following, the extensions of fuzzy sets proposed to model cognitive categories should be understood as such. As for the modeling of cognitive categorization itself, an attempt to model certain aspects of it is developed with the extended theory of approximate reasoning presented in section 7, which is used in a computational system of information retrieval outlined in section 9.

3. Mathematical Background

Let X denote a nonempty *universal set* under consideration. Let $\mathbb{P}(X)$ denote the power set of X. An element of X represents a possible value for a variable x. X can be *countable* or *uncountable.*

3.1 Uncertainty

George Klir [1993; Klir and Yuan, 1995] classifies uncertainty into two main forms: *ambiguity* and *fuzziness*. Ambiguity is further divided into the categories of *nonspecificity* and *conflict*. Mathematically ambiguity is identified with the existence of one-to-many relations, that is, when several alternatives exist for the same question or proposition. Nonspecificity is associated with unspecified alternatives, and conflict with the existence of several alternatives with some distinctive characteristic. Dempster-Shafer Theory (see below) provides an ideal framework for the study of ambiguity, as it enlarges the scope of traditional probability theory. Fuzziness is identified with lack of sharp distinctions. Fuzzy sets (see below) are usually used to formalize this kind of uncertainty. A measure of fuzziness is defined as the lack of distinction between a set and its complement [Yager, 1979, 1980]. In [Rocha, 1997a, 1997b] measures of uncertainty needed to measure the information content of evidence sets presented next were developed. In particular, such measures were defined for both discrete and nondiscrete domains. Please refer to [Rocha, 1997a, 1997b] for a more detailed discussion of uncertainty.

3.2 Dempster-Shafer Theory of Evidence

Evidence theory, or *Dempster-Shafer Theory* (DST) [Shafer, 1976], may be defined in terms

of a set function m: $\mathbb{P}(X)$ [0, 1], referred to as a *basic probability assignment*, such that m (emptyset)=0 and SUM $m(A)$=1. The value $m(A)$ denotes the proportion of all available evidence which supports the claim that A in $\mathbb{P}(X)$ approximately represents the actual value of our variable x. DST is based on a pair of nonadditive measures: *belief* (Bel) and *plausibility* (Pl) uniquely obtained from m. Given a basic probability assignment m, Bel and Pl are determined for all A in $\mathbb{P}(X)$ by the equations:

$$\mathrm{Pl}(A) = \sum_{B \cap A \neq \emptyset} m(B)$$

the expressions above imply that belief and plausibility are dual measures related by:

$$\mathrm{Pl}(A) = 1 - \mathrm{Bel}(A^c)$$

for all A in $\mathbb{P}(X)$, where A^c represents the complement of A in X. It is also true that $\mathrm{Bel}(A) < \mathrm{Pl}(A)$ for all A $\mathbb{P}(X)$. Notice that [Shafer, 1976, page 38] , "$m(A)$ measures the belief one commits exactly to A, not the total belief that one commits to A." Bel(A), the total belief committed to A, is instead given by the sum of all the values of m for all subsets of A.

Any set A in $\mathbb{P}(X)$ with $m(A) > 0$ is called a *focal element*. A *body of evidence* is defined by the pair ($\mathbb{F}$, m), where $\mathbb{F}$ represents the set of all focal elements in X, and m the associated basic probability assignment. The set of all bodies of evidence is denoted by B. In the context of evidence theory, the universal set X is referred to as the *frame of discernment*. Given two pairs of dual belief-plausibility measures, Bel_1-Pl_1, Bel_2-Pl_2, over the same of frame of discernment X, but based on different bodies of evidence $(\mathbb{F}, m)_1$, $(\mathbb{F}, m)_2$, the resulting, combined, body of evidence, $(\mathbb{F}, m)_{1,2}$, is defined by the following basic probability assignment:

$$m_{1,2}(C) = \frac{\sum_{A_i \cap B_j = A} m_1(A_i) m_2(B_j)}{1 - \sum_{A_i \cap B_j = \emptyset} m_1(A_i) m_2(B_j)}$$

where $\mathbb{F}_{1,2}$ is the set of all non-empty subsets C of X resulting from the intersection of each focal element A_i of $\mathbb{F}_1$ with each focal element B_j of $\mathbb{F}_2$. This expression is referred to as the *Dempster's rule of combination*.

3.3 Fuzzy Sets and Interval Valued Fuzzy Sets

A crisp set entails no uncertainty in its membership assessment: if an element x of X is a member of a set A in X, then it will not be a member of its complement A^c in X. A fuzzy set introduces fuzziness as the above law of contradiction is violated: x can both be a member (to a degree) of A and A^c. A (standard) fuzzy set A is defined by a membership function $A(x)$: $X \rightarrow [0,1]$. Fuzzy sets can be extended to *interval valued fuzzy sets* (IVFS): $A(x)$: $X \rightarrow \mathbb{I}([0,1])$, where $\mathbb{I}$ represents the set of intervals in [0, 1]. IVFS offer, in addition to fuzziness, a nonspecific description of membership in a set; and they do so with very little information requirements. An IVFS A, for each x in X, captures two forms of uncertainty: *fuzziness* (as in the case of fuzzy sets) and *nonspecificity*. The Fuzziness of the membership degrees of standard fuzzy sets, is absolutely specific. When we create a fuzzy set we have perfect knowledge of the degree to which a certain element x of X belongs to A. In contrast, when we create an IVFS we have nonspecific knowledge of the degree of membership; hence the utilization of an interval to describe the membership of x in A.

4. Sets and Cognitive Categorization

4.1 Fuzzy Sets and the *Prototype Combination Problem*

As previously discussed, fuzzy sets are actually fairly accurate representations of categories simply because they are able to represent prototypicality (understood as degree of representativeness); how the prototype degrees are constructed is, on the other hand, a different matter. Fuzzy sets are simple representations of categories which need much more complicated models of approximate reasoning than those fuzzy predicate logic alone can provide in order to satisfactorily model cognitive categorization processes. Critics [Osherson and Smith, 1981; Smith and Osherson, 1984; Lakoff, 1987] have shown that the several fuzzy set connectives (e.g. conjunction and disjunction) cannot conveniently account for the prototypicality of the elements of a complex category, which may depend only partially on the prototypicality of these elements in the constituent categories and may even be larger (or smaller) than in all of these. This is know as the *prototype combination problem*.

A complex category is assumed to be formed by the connection of several other categories. Approximate reasoning defines the sort of operations that can be used to instantiate this association. Smith and Osherson's [1984] results, showed that a single fuzzy connective cannot model the association of entire categories into more complex ones. Their analysis centered on the traditional fuzzy set connectives of (max-min) union and intersection. They observed that max-min rules cannot account for the membership degrees of elements of a complex category which may be lower than the minimum or higher than the maximum of their membership degrees in the constituent categories. Their analysis is very incomplete regarding the full-scope of fuzzy set connectives, since we can use other operators [see Dubois and Prade, 1985], to obtain any desired value of membership in the [0, 1] interval of membership. However, their basic criticism remains valid: even if we find an appropriate fuzzy set connective for a particular element, this connective will not yield an accurate value of membership for other elements of the same category. Hence, a model of cognitive categorization which uses fuzzy sets as categories will need several fuzzy set connectives to associate two categories into a more complex one (in the limit, one for each element). Such model will have to define the mechanisms which choose an appropriate connective for each element of a category. No single fuzzy set connective can account for the exceptions of different contexts, thus the necessity of a complex model which recognizes these several

contexts before applying a particular connective to a particular element. Therefore, a model of cognitive categorization based solely on fuzzy sets and their connectives will be very complicated and cumbersome.

The prototype combination problem is not only a problem for fuzzy set models, but for all models of combination of prototype-based categories. Fodor [1981] insists that though it is true that prototype effects obviously occur in human cognitive processes, such structures cannot be fundamental for complex cognitive processes (high level associations): "there may, for example, be prototypical cities (London, Athens, Rome, New York); there may even be prototypical *American Cities* (New York, Chicago, Los Angeles); but there are surely not prototypical *American cities situated on the east coast just a little south of Tennessee.*"[Ibid, page 297] As Clark [1993] points out, the problem with Fodor's point of view, and indeed the reason why fuzzy set combination of categories fails, is that "he assumes that prototype combination, if it is to occur, must consist in the linear addition of the properties of each contributing prototype." [Ibid, page 107] Clark proposes the use of connectionist prototype extraction as an easy way out of this problem. In fact, a neural network trained to recognize certain prototype patterns, e.g. some representation of "tea" and "soft drink", which is also able to represent a more complex category such as "ice tea", "does not do so by simply combining properties of the two 'constituent' prototypes. Instead, the webs of knowledge structure associated with each 'hot spot' engage in a delicate process of mutual activation and inhibition." [Ibid, page 107] In other words, complex categories are formed by nonlinear, emergent, prototype combination.

As Clark points out, however, this ability to nonlinearly combine prototypes in connectionist machines is a result of the pre-existence of a (loosely speaking) semantic metric which relates all knowledge stored in the network. Through the workings of the network with its inhibition and activation signals, new concepts can be learned which must somehow relate to the existing knowledge previously stored. Therefore, any new knowledge that a connectionist device gains, must be somehow related to previous knowledge. This dependence prevents the sort of open-ended conceptual combination that we require of higher cognitive processes.

This problem might be rephrased by saying that connectionist devices can only make nonlinear prototype combinations given a small number of contexts. The brain may use a network to classify, say, sounds, another one images, and so forth. In their own contexts, each network combines prototypes into more complex ones, but they cannot escape their own contexts. I believe, with Clark, that connectionist machines are nonetheless very powerful, even given these constraints. The approach I am about to follow, is not proposed to be used instead of connectionist devices, but one that may offer a higher level treatment of the contextual problem in prototype combination. In fact, in section 9, a computational model is presented that even though not using connectionist machines in the strong sense [van Gelder, 1992], uses networked relational databases that also possess distributed semantic semi-metrics and which can approach this contextual problem.

4.2 Interval Valued Fuzzy Sets

As discussed in the previous section, approximate reasoning does not model effectively the combination of prototypical categories. It can only work on very limited contexts, whose categories can be formed from the linear combination of constituent categories. The

Introduction of a theory of approximate reasoning based on interval valued fuzzy sets [Gorzaczany, 1987; Türken, 1986] represents a step forward in the modeling of cognitive categorization, as it offers a second level of uncertainty, but it only slightly improves the contextual problem referred above. The membership degrees of IVFS are nonspecific (see section 3.3). This second dimension of uncertainty allows us to interpret the interval of membership of an element in a category as the membership degree of this element *according* to several different contexts, which we cannot a priori identify.

In particular, Turksen's concept combination mechanisms are based on the separation of the disjunctive and conjunctive normal forms of logic compositions in fuzzy logic. A disjunctive normal form (DNF) is formed with the disjunction of some of the four primary conjunctions, and the conjunctive normal form (CNF) is formed with the conjunction of some of the four primary disjunctions, respectively:
$A \cap B$, $A \cap \bar{B}$, $\bar{A} \cap B$, $\bar{A} \cap \bar{B}$ and $A \cup B$, $A \cup \bar{B}$, $\bar{A} \cup B$, $\bar{A} \cup \bar{B}$. In two-valued logic the CNF and DNF of a logic composition are equivalent: CNF = DNF. Turksen observed that in fuzzy logic, for certain families of conjugate pairs of conjunctions and disjunctions, we have instead DNF $\subseteq$ CNF for some of the fuzzy logic connectives. He then proposed that fuzzy logic compositions could be represented by IVFS's given by the interval [DNF, CNF] of the fuzzy set connective chosen [Turksen, 1986]. With IVFS based connectives, Turksen was able to deal more effectively with the shortcomings of a pure fuzzy set approach. In his model, two fuzzy sets are combined into an IVFS. The fuzzy and nonspecific degrees of membership of the elements in the category obtained, can be interpreted as inclusion in a category according to several possible, fuzzy degrees.

Turksen's model simplifies the pure fuzzy set approach since we will find more categories which can be combined into complex categories with a single connective used for all elements of the universal. The IVFS approach provides a way to acknowledge the existence of contextual nonspecificity in complex category formation, thus producing a more accurate representation of different forms of uncertainty present in such processes. The problem is that categories demand membership values which more than nonspecific can be conflicting. That is, the contextual effects may need more than an interval of variance to be accurately represented. Also, even though IVFS use nonspecific membership, thus allowing a certain amount of contextual variance, the several contexts are not explicitly accounted for in the categorical representation. Section 5 proposes set structures which (i) capture all recognizable forms of uncertainty in their membership representation, (ii) point explicitly to the contexts responsible for a certain facet of their membership representation, and (iii) in so doing, introduce a formalization of belief.

5 Evidence Sets: Membership, Belief, and Context

An alternative way to represent an IVFS A is to consider that for every element x of X, there is a body of evidence (F^x, m^x) defined on the set of all intervals of [0,1], I, with a single focal element given by the interval $I^x = [I^x_{inf}, I^x_{sup}] \subseteq [0,1]$. The basic probability assignment function m^x assumes the value 1 for this single focal element, representing our belief that the degree of membership of element x of X in A is (with all certainty) in the sub-interval I^x of [0, 1]. In other words, our *judgement* of the (nonspecific) degree of membership, I^x, of x

in set A indicates that we fully believe it is correct. Notice that the universal set of the IVFS is X, but the universal set of the body of evidence is the unit interval [0, 1]. It is now clear that an IVFS is a very special case of a more general structure which I refer to as *evidence set* [Rocha, 1994, 1995, 1997a]. An *evidence set A* of X, is defined by a membership function of the form:

$$A(x): X \rightarrow \mathbb{B}[0, 1]$$

where, $\mathbb{B}[0, 1]$ is the set of all possible bodies of evidence $(\mathbb{F}^x, m^x)$ on $\mathbb{I}$. Such bodies of evidence are defined by a basic probability assignment m^x on $\mathbb{I}$, for every x in X. Thus, evidence sets are set structures which provide interval degrees of membership, weighted by the probability constraint of DST. They are defined by two complementary dimensions: membership and belief. The first represents a fuzzy, nonspecific, degree of membership, and the second a subjective degree of belief on that membership, which introduces conflict of evidence as several, subjectively defined, competing membership intervals weighted by the basic probability constraint are created (focal intervals). Figure 1 depicts a non-consonant [Rocha, 1995] evidence set with three focal elements.

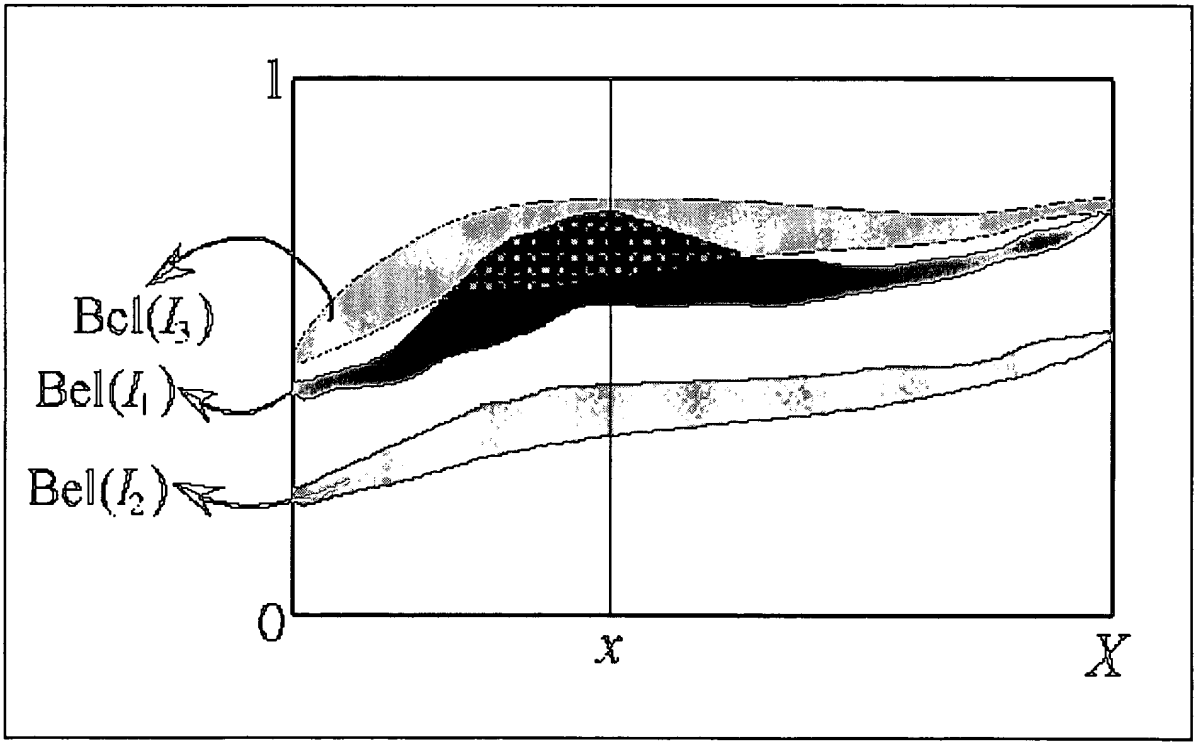


Figure 1: Non-consonant evidence set with three focal elements

The interpretation I suggest for the multiple intervals of evidence sets, defines each interval of membership I_j^x, with its correspondent evidential weight $m^x(I_j^x)$, as the representation of the prototypicality of a particular element x of X in category A *according* to a particular *perspective*. Thus, each element x of an evidence set A has its membership defined as several intervals representing different, possibly conflicting, perspectives. An IVFS refers to the case where we have a single perspective on the category in question, even if it admits a nonspecific representation (an interval). The ability to maintain several of these

perspectives, which may conflict at times allows a model of cognitive categorization or knowledge representation to directly access particular contexts affecting the definition of a particular category, which is essential for radial categories. In other words, the several intervals of membership of evidence sets refer to different perspectives which explicitly point to particular contexts.

The degrees of belief on which evidence theory is based do not aspire to be objective claims about some real evidence, they are rather proposed as *judgements*, formalized in the form of a degree [Shafer, 1976, page 21]. Likewise, Rosch's prototypes are not assumed to be an objective grading of concepts in a category, but rather judgements of some uncertain, highly context-dependent, grading [Rosch, 1978, page 40]. Evidence sets offer a way to model these ideas since an *independent*(1), unconstrained, membership grading of elements (concepts) in a category is offered together with an explicit formalization of the belief posited on this membership. For evidence sets, membership in a category and judgments over membership are different, complementary, qualities of prototypicality. None of the other structures so far presented is able to offer both an independent characterization of membership and a formalization of judgments imposed on this membership. Traditional set structures (crisp, fuzzy, or interval-valued) alone offer only an independent degree of membership, while evidence theory by itself offers primordially a formalization of belief which constrains the elements of a universal set with a probability restriction (more on this in section 8).

Regarding the previously discussed connectionist extraction of prototypes, notice that evidence sets, as any set structure, have independent, unconstrained membership. Connectionist prototypes are implicitly defined by a semantic metric constraining the elements of the categorizing universe. The existence of such metrics may be very important for cognitive categorization. However, evidence sets are merely proposed as models of cognitive categories, it is up to the model of cognitive categorization to supply additional constraints such as semantic metrics. As a higher level structure, it is very important that Evidence Sets do not have such constraints a priori, in fact, it is precisely their advantage over connectionist devices which are not flexible enough to allow users to arbitrarily change constraints and contexts on prototype-based categories. In section 7, approximate reasoning methods are proposed which shall be used in Section 9 to define an information retrieval system that in turn constrains Evidence Sets with context-specific semantic metrics.

6. Evidence Sets and Uncertainty

A fuzzy set captures fuzziness in a specific way; an IVFS introduces nonspecificity; a consonant evidence set (nested focal intevals) introduces grades or shades of nonspecificity; and finally, a nonconsonant evidence set introduces conflict as we have cases where the degree to which an element is a member of a set is represented by disjoint focal intervals of [0, 1] with different evidential strengths. The three forms of uncertainty are clearly present in human cognitive processes. More than simply measuring fuzziness, as approximate reasoning models do, models of uncertain reasoning based on evidence sets need to effectively measure all the three uncertainty forms. Hence, we need a 3-tuple of measures of the 3 main kinds of uncertainty to aid us in the decision making steps of our uncertain reasoning models: (*Fuzziness, Nonspecificity, Conflict*). [Rocha et al, 1996; Rocha, 1997a, 1997b].

The three forms of uncertainty define a 3 dimensional uncertainty space for set structures, where crisp sets occupy the origin, fuzzy sets the fuzziness axis, IVFS the fuzziness-nonspecificity plane, and evidence sets most of the rest of this space. The total uncertainty, *U*, of an evidence set *A* is defined by: $U(A) = (IF(A), IN(A), IS(A))$. The three indices of uncertainty, which vary between 1 and 0, *IF* (fuzziness), *IN* (nonspecificity), and *IS* (conflict) were introduced in [Rocha, 1996a, 1997a, 1997b], where it was also proven that *IN* and *IS* possess good axiomatic properties wanted of information measures. For a complete discussion, please refer to [Rocha et al, 1996; Rocha, 1997a, 1997b].

7. Belief-Constrained Approximate Reasoning

7.1 Uncertainty Increasing Operations Between Evidence Sets

The operations of complementation, intersection, and union are the most basic connectives in a theory of approximate reasoning. Here I discuss only these operators, since all other connectives can be easily constructed from these. Naturally, complementation, intersection, and union as defined below for evidence sets subsume, as special cases, the same operations for IVFS and fuzzy sets.

7.1.1 Complementation

The interval valued membership function of elements of *X* in an IVFS *A* is given by: $A(x) = I^x = [I^x_{inf}, I^x_{sup}] \subseteq [0,1]$. Its complement can be defined as the negation of the interval limits in reverse order: $A^c(x) = (I^x)^c = [1-I^x_{sup}, 1-I^x_{inf}]$ [Gorzaczany, 1987]. The membership function of an evidence set *A* of *X* is given, for each *x*, by *n* intervals weighted by a basic probability assignment m^x:

$$A(x) = \left\{\left\langle I_1^x, m_1^x\right\rangle, \left\langle I_2^x, m_2^x\right\rangle, \cdots, \left\langle I_n^x, m_n^x\right\rangle\right\}$$

The complement of an evidence set [Rocha, 1997a, 1997c] is defined as the complement of each of its interval focal elements with the preservation of their respective evidential strengths:

$$A^c(x) = \left\{\left\langle \left(I_1^x\right)^c, m_1^x\right\rangle, \left\langle \left(I_2^x\right)^c, m_2^x\right\rangle, \cdots, \left\langle \left(I_n^x\right)^c, m_n^x\right\rangle\right\}$$

7.1.2 Intersection

The intersection of two IVFS [Gorzaczany, 1987] is defined as the minimum of their respective lower and upper bounds of their membership intervals. Given two intervals of [0, 1] $I = [I_L, I_U] \subseteq [0,1]$ and $J = [J_L, J_U]$, the minimum of both intervals is an interval $K = \mathrm{MIN}(I,J) = [\mathrm{MIN}(I_L, J_L), \mathrm{MIN}(I_U, J_U)]$. Given two evidence sets *A* and *B* defined for each *x* of *X* by:

$$A(x) = \left\{\left\langle I_i^x, m_A^x(I_i)\right\rangle\right\}, \quad i = 1,\ldots,n$$

and

$$B(x) = \left\{\left\langle J_j^x, m_B^x(J_j)\right\rangle\right\}, \quad j = 1,\ldots,m$$

where I_i and J_j are intervals of [0,1]. Their intersection is an evidence set $C(x) = A(x)\ B(x)$, whose intervals of membership K_k and respective basic probability assignment $m_C(K_k)$ are defined by:

$$m_C^x(K_k^x) = \sum_{MIN(I_i^x, J_j^x) = K_k^x} m_A^x(I_i^x) \cdot m_B^x(J_j^x)$$

7.1.3 Union

The union of two IVFS [Gorzaczany, 1987] is defined as the maximum of their respective lower and upper bounds of their membership intervals. Given two intervals of [0, 1] $I = [I_L, I_U] \subseteq [0,1]$ and $J = [J_L, J_U]$, the maximum of both intervals is an interval $K = \mathrm{MAX}(I,J) = [\mathrm{MAX}(I_L, J_L), \mathrm{MAX}(I_U, J_U)]$. Given two evidence sets A and B defined by (3) and (4), their union is an evidence set $C(x) = A(x)\ B(x)$, whose intervals of membership K_k and respective basic probability assignment $m_C(K_k)$ are defined by:

$$m_C^x(K_k^x) = \sum_{MAX(I_i^x, J_j^x) = K_k^x} m_A^x(I_i^x) \cdot m_B^x(J_j^x)$$

7.1.4 Increasing Uncertainty

By utilizing the connectives (5) and (6), the uncertainty of our models tends to increase, as two bodies of evidence on the unit interval are combined into a new one, by preserving most perspectives (contexts) involved. There are at least as many intervals in the combined set as the minimum of intervals in the combining sets. In other words, if i^x and j^x represent the number of intervals (perspectives) present, respectively, in combining sets A and B for element x, then the combined set C will have at least MIN($|\ i^x\ |$, $|\ j^x\ |$) intervals for concept x. An alternative to this way of combining evidence sets is described below.

7.2 Uncertainty Decreasing Operation Between Evidence Sets

We can combine evidence sets by preserving all their perspectives (though with reduced weights as the joined basic assignment must still add up to 1) as above, thus increasing the uncertainty complexity, or we can combine them only according to the coherent perspectives (those aiming at the same intervals) by utilizing Dempster's rule of combination (1) presented in section 3.2 , and decrease the uncertainty complexity. Given two evidence sets A and B defined by (3) and (4), their uncertainty decreasing combination is an evidence set $C(x) = A(x) \square B(x)$, whose intervals of membership K_k and respective basic probability assignment $m_C(K_k)$ are defined by:

$$m_C^x(K_k^x) = \frac{\sum_{I_i^x \cap J_j^x = K_k^x} m_A^x(I_i^x) \cdot m_B^x(J_j^x)}{1 - \mathbb{K}}$$

$$\text{for } K_k^x \neq \varnothing, \text{ where } \mathbb{K} = \sum_{I_i^x \cap J_j^x = \varnothing} m_A^x(I_i^x) \cdot m_B^x(J_j^x)$$

This operation eliminates all focal elements which do not coincide (or intersect) in both bodies of evidence being combined, while the operations of section 7.1 maintain some evidential weight for these, though enhancing those that do intersect.

Dempster's rule of combination is used to combine different bodies of evidence over the same frame of discernment. It is an all or nothing rule, that is, if the focal elements of two distinct bodies of evidence being combined are disjoint, no combination is possible. In this situation, in DST, if we still consider that there is relevant interaction between the two bodies of evidence which our frame of discernment cannot capture, then we either rethink our basic probability assignments or the frame of discernment is changed by introducing new elements common to both bodies of evidence. Now consider that our model of categorization, by utilizing Dempster's rule, reaches a combination of categories whose bodies of evidence are completely incoherent. That is, no new category is obtainable. If this result is reached in some intermediate step of an approximate reasoning process, the process is naturally stopped. To be able to continue with this process, we have to obtain some transitional category. Since the frame of discernment of the belief attributes of an evidence set is the membership unit interval, we cannot aim to refine it in any way. For this reason, I have proposed uncertainty decreasing and increasing operations for evidence sets. If the evidence sets being combined are at least partially coherent, we can use Dempster's rule which will reduce the uncertainty present. If this coherency is not attainable, we can choose an uncertainty increasing operation which largely maintains the evidence from both structures being combined, until a more coherent state of evidence is encountered at a later stage.

The uncertainty decreasing operation can be used when we have coherent evidence of membership in combining evidence sets, and when we wish to reduce dramatically the amount of uncertainty present in some simulation of human reasoning processes. In an artificial system, this operation might be identified we fast decision-making processes. Say, if we possess two categories which must be combined in order to make a fast decision, then uncertainty must be reduced and the most coherent result chosen. On the other hand, if we do not have coherent membership evidence, or if we do not need to engage in fast decision making, but instead desire to search for more conflicting, far-fetched, associations (from wildly different contexts), then the uncertainty increasing operations should be chosen.

8. Evidence Sets and Evidence Theory

So far I have discussed set structures as models of cognitive categories, from crisp sets to evidence sets I have stressed that any mathematical model of cognitive categories must offer (i) degrees of inclusion in the category/set, (ii) an accurate account of uncertainty forms in their membership values, and (iii) a way in for context-dependencies and subjective aspects of categories. I have proposed that evidence sets fulfill these three requirements. A natural

question now is, why is DST not enough by itself to effectively model cognitive categories? We can think of the frame of discernment of DST as the universe of possible values for a variable x representing the possible elements (or concepts) of a universe of discourse. A category can be defined as a body of evidence defined on such universe. Each focal element, can be seen as a possible perspective for the category.

8.1 Upper and Lower Probabilities Interpretation

Let us consider that a category is defined by a body of evidence ($\mathbb{F}$, m) on a universal set X. In other words, the category will be defined by a set $\mathbb{F}$ of subsets of X (focal elements) with associated basic probability assignment m. Plausibility and belief measures can be constructed from ($\mathbb{F}$, m) as defined in section 3.2. Following Dempster's [1967] original interpretation of plausibility and belief measures as upper and lower probabilities, respectively, we can understand these probability limits as offering a nonspecific (interval-valued) membership of subsets of X in the category, which would satisfy the first requirement above. Nonetheless, several problems are encountered with this model of categories. First, notice that the basic probability assignment values must add up to one (see section 3.2), this constrains the category as it introduces a dependency on its elements. That is, because of the probabilistic constraint, the value of membership of an element, which would be given here by the belief-plausibility interval, would be constrained by the value of membership of other elements. Specifically, their individual membership is not free to attain any value as it is desired of a set structure or a cognitive category. Furthermore, membership in a category is not attributed to singletons but to subsets of the universal set. In addition, the second and third requirements are not satisfied as conflict is not captured, and no account of context is included, in the individual membership values.

8.2 Belief Interpretation

Consider now that a category is still defined by the body of evidence ($\mathbb{F}$, m), only now, more in line with Shafer's [1976] interpretation, the basic probability assignment function m will identify the portions of belief ascribed exactly to the focal elements $\mathbb{F}$. This way, each exact portion of belief and its associated focal element can be related to a particular context in a larger imbedding model. In other words, the sort of categories we obtain with this interpretation are formed by crisp subsets of the frame of discernment with associated belief values: membership is all or nothing, but belief is graded. In a way, we have classic categories with an account of belief, subjectivity, and a way in for context-dependencies in a larger model of categorization. Clearly, this interpretation satisfies the third requirement but not the first and the second.

8.3 Generalized Dempster-Shafer Theory

Several ways of extending the DST to a fuzzy set framework have been proposed. Probably the most general and well known approach is John Yen's [1990] generalization. Basically, the idea is to move from crisp to fuzzy focal elements. In this case, we no longer have classical categories, as degrees of membership are introduced, thus satisfying the first requirement in addition to the third requirement already satisfied by the second interpretation of evidence theory in the previous section. Naturally, to satisfy the second

requirement, that is, to obtain an accurate account of uncertainty forms in the membership degrees of a set/category's elements we can extend the fuzzy focal elements to interval-valued focal elements, or even more generally to sets of fuzzy sets. This seems to satisfy all of the three requirements above, so, why are evidence sets preferable over generalized evidence theory as models of categories? The next subsection should answer this question.

8.4 Evidence Sets : Independent Membership

Evidence sets have unconstrained membership; that is, the values of membership for each element x of the universal set X are independent of each other. In contrast, the categories defined solely with evidence theory in the previous sections, are set oriented, that is, they define categories with focal elements which are subsets of X. Thus, the evidence a particular context offers is associated with a set of singletons rather than with a singleton itself. Naturally, a singleton can also be represented by a set, but if focal elements are singletons, then we will need many focal elements to represent a category, and since their respective evidential weights given by the basic probability assignment must add up to one, each singleton will necessarily have a small degree of belief associated with it. In other words, the belief we have that a certain singleton belongs to a category, will be dependent on the belief we ascribe to other singletons. This kind of dependence is not desirable of a model of a category. The inclusion of an element in a category should not necessarily be dependent on other elements already included in it. A larger model of categorization may impose these constraints at a higher level, but the basic mathematical structures used should not impose them at the onset.

An evidence set allows a complete separation of membership and belief between elements in a category since an account of belief is not used to constrain the elements of the universal set but to constrain their respective membership values in the unit interval. Thus, the membership/belief of an element x is independent from that of another element y. It is important to realize that belief is still constrained *for each individual* membership qualification, in other words, the basic probability assignment used to qualify the possible intervals of membership, must still add up to one. With this independent quantifiability of membership/belief for each element in a universal set, the contexts that affect an element's membership in a category can be completely different from element to element, a desirable characteristic for radial categories.

9. Computing Categories in Information Retrieval

In this section a conversational, collaborative, adaptive, knowledge management system for databases that uses evidence sets as categorization mechanisms is presented. Its objective is the definition of a human-machine interface that can capture more efficiently the user's interests through an interactive question-answering process. It also attempts to model certain aspects of cognitive categorization processes that use linguistic categories as higher-level short-term constructs generated by lower-level connectionist memory banks. The model offers an expansion of Nakamura and Iwai's [1982] data-retrieval system which is expanded from a fuzzy set to an evidence set framework. The evidence set expansion allows the construction of categories from several databases simultaneously.

Each database is characterized by a network structure with two different kinds of objects: *Concepts* x_i (e.g. Keywords) and *Properties* p_i (e.g. data records like books). Each concept is

associated with a number of properties which may be shared with other concepts. Based on the amount of properties shared with one another, a measure of similarity, *s*, can be constructed for concepts x_i and x_j:

$$s(x_i,x_j) = \frac{N(x_i \cap x_j)}{N(x_i \cup x_j)} = \frac{N(x_i \cap x_j)}{N(x_i)+N(x_j)-N(x_i \cap x_j)}$$

where $N(x_i)$ represents the number of properties that directly qualify concept x_i, $N(x_i)$ represents the number of properties that directly qualify concept x_i, $N(x_i \cup x_j)$ represents the number of properties that directly qualify *both* x_i or x_j, and $N(x_i \cap x_j)$ represents the number of properties that directly qualify *either* x_i or x_j. The inverse of the similarity, *s*, creates a measure of distance[(2)], *d*:

$$d(x_i,x_j) = \frac{1}{s(x_i,x_j)}$$

The distances between directly linked concepts are calculated using (9). After this, the shortest path is calculated between indirectly linked concepts. The algorithm allows the search of indirect distances up to a certain level. The set of *n-reachable* concepts from concept x_i, is the set of concepts that have no more that *n* direct paths between them. If we set the algorithm to paths up to level *n*, all concepts that are only reachable in more than *n* direct paths from x_i will have their distance to x_i set to infinity.

9.1 The Long-Term Networked Memory Structure

The *Local Knowledge Context* X_k is the substructure of database *k* defined solely by the concepts and their relative distance d_k as constructed with the semi-metric (9). Its purpose is to capture human knowledge by keeping a record of relationships between concepts, as well as a measure of their similarity. It is not a connectionist structure in the strong sense that concepts are not superposed [van Gelder, 1992] over the network but localized in recognizable nodes. However, in addition to localized nodes it does possess a distributed semi-metric space relating all knowledge as desired of connectionist memory [Clark, 1993]. This space is the lower-level structure of the system, the long-term memory of the database. It is from this semantic semi-metric that temporary prototype categorizations can be formed to model the "on the hoof" categories previously discussed.

The system's relations are unique to it, and reflect the actual semantic constraints established by the set of *properties* (data records) it stores. Thus, the semantic semi-metric defined by (9), reflects the actual inter-significance of *concepts* (keywords) for the system and its users. The same concept in different databases will be related differently to other concepts, because the actual properties stored will be distinct. The properties a database stores are a result of its history of utilization and deployment of information by its users. In this sense, the long-term networked memory structure reflects a unique subjectivity developed by the history and dynamics of information storage and usage. Thus, each local

knowledge space X_k from database k captures the knowledge that its community of users have accumulated in some area. Figure 2 depicts such structure with two different relational databases.

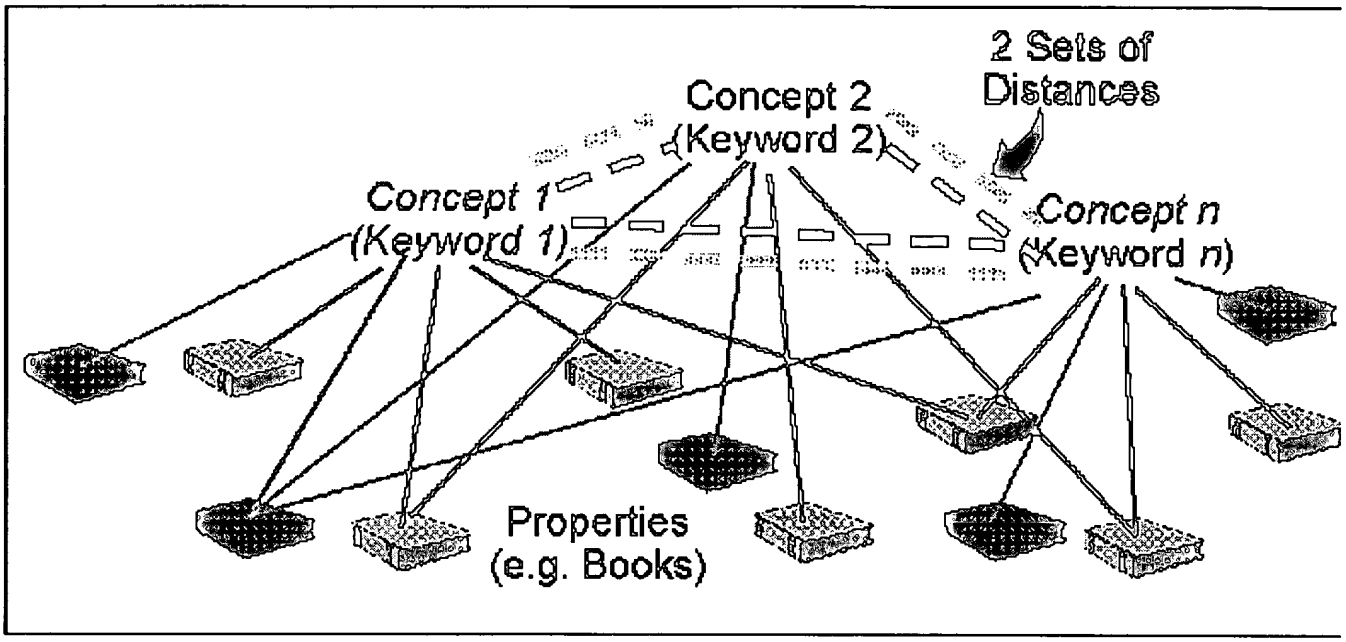


Figure 2: Structure of 2 distinct databases that possess at least some key-words in common. A differer distance semi-metric is constructed for each one

The *Total Knowledge Space X* of this structure is the set of all concepts in the n_d included databases, that is:

$$X = \bigcup_{k=1}^{n_d} X_k$$

Furthermore, the system has n_d different distance semi-metrics, d_k, associated with it. Each distance semi-metric is still built with equation (9) for some acceptable level of n-reachable concepts. But since each of the n_d databases has a different concept-property pattern of connectivity, each distance semi-metric d_k will be different. When a concept exists in one database and not on another, its distance to all other concepts of the second database is set to infinity. If the databases reflect similar communities of users, naturally their distance semi-metrics will tend to be more similar. This distinction between the several local knowledge contexts provides the system with intrinsic contextual conflict in evidence.

9.2 Short Term Categorization Processes

With their several intervals of membership weighted by the basic probability assignment of DST, evidence sets can be used to quantify the relative interest of users in each of the knowledge contexts stored in the n_d databases. Given the underlying relations imbedded in the knowledge space, the system uses a question-answering process to capture the interests

of users in terms of this relational structure. In other words, the system constructs its own internal categories in interaction with the community of users. The extended evidence set approximate reasoning operations of intersection and union can be used to define such a conversational process.

The system starts by presenting users with the several networked databases available, who have to probabilistically grade them. That is, weights must be assigned to each database which must add to one (in order to build basic probability assignment functions). The selected databases define the several contexts which the system uses to construct its categories. Once this is defined, the question-answering algorithm is as follows:

1. The user selects the n_d databases of interest and their respective weights m_k.
2. The user inputs an *initial concept of interest* (one of the key-words) $x_i \in X$.
3. The system creates an evidence set membership function centered on x_i and affecting all its close neighbors using a construction defined below (equations (10) to (14)). This resulting evidence set of X represents a category that keeps the user's interests in terms of the system's own relations: *The learned category* $A(x)$.
4. The system calculates the total uncertainty of the learned category in its forms of fuzziness, nonspecificity, and conflict (as discussed in section 6). If total uncertainty is below a pre-defined small value the process stops, otherwise continue.
5. Another concept $x_j \in X$ is selected. x_j is selected in order to potentially minimize the uncertainty of the learned category, that is, the most uncertain concepts with the most uncertain neighborhoods are selected.
6. The user is asked whether or not she is interested in x_j.
7. If the answer is "YES" another membership function as defined by (14) is created over x_j, and an evidence set union is performed with the previous state of the learned category.
8. If the answer is "NO" the inverse of (14) is created over x_j, and an evidence set intersection is performed.
9. The system calculates the total uncertainty of the learned category in its forms of fuzziness, nonspecificity, and conflict.
10. If the uncertainty of the learned category is smaller than half the maximum value attained previously, the system stops since the learned category is considered to have been successfully constructed. Otherwise computation goes back to step 5.

Several approaches can be used to define evidence set membership functions for the algorithm above. The scheme I follow here starts by building bell-shaped fuzzy membership functions for each of the n_d distance semi-metrics d_k of X [Nakamura and Iwai, 1982]. Thus we obtain n_d different fuzzy subsets of X defined by fuzzy membership functions for "YES" or "NO" responses given to concept x_i as follows:

$$f^{d_k}_{YES,x_i}(x) = e^{\left(-\alpha |x - x_i|^{1/2}_{d_k}\right)}, \; k = 1 \ldots n_d, \; x_i \in X$$

and

$$f^{d_k}_{NO,x_i}(x) = 1 - f^{d_k}_{YES,x_i}(x)$$

where the parameter controls the spread of the bell-shaped functions.

The next step is the construction of IVFS from these n_d fuzzy sets, using Turksen's DNF $\subseteq$ CNF combinations (see section 4.2). All pairs of the n_d fuzzy sets given by either (10) or (11) for the "YES" or "NO" case respectively are combined to obtain $(n_d^2 - n_d)/2$ IVFS for the union combination and $(n_d^2 - n_d)/2$ for the intersection combination. Each pair of fuzzy sets is combined with the CNF and DNF forms of disjunction (union) and conjunction (intersection) in order to form two IVFS whose respective intervals of membership are defined by the DNF $\subseteq$ CNF bounds for the standard union and intersection. Thus, from n_d fuzzy sets we obtain $n_d^2 - n_d$ IVFS. Since the "YES" and "NO" functions are combined in exactly the same way, in the following I define the IVFS combination for a series of n_d fuzzy set membership functions that can refer to either "YES" or "NO". Formally, a pair of fuzzy set membership functions (for semi-metrics d_k and d_l) is combined to obtain two IVFS:

$$IVf^{d_k \cup d_l}_{x_i}(x) = \left[f^{d_k}_{x_i}(x) \underset{DNF}{\cup} f^{d_l}_{x_i}(x); f^{d_k}_{x_i}(x) \underset{CNF}{\cup} f^{d_l}_{x_i}(x) \right]$$

for union, and

$$IVf^{d_k \cap d_l}_{x_i}(x) = \left[f^{d_k}_{x_i}(x) \underset{DNF}{\cap} f^{d_l}_{x_i}(x); f^{d_k}_{x_i}(x) \underset{CNF}{\cap} f^{d_l}_{x_i}(x) \right]$$

for intersection, where for two fuzzy sets $A(x)$, $B(x)$ the following definitions apply (the over line denotes set complement):

$$A \underset{DNF}{\cap} B = A \cap B$$
$$A \underset{CNF}{\cap} B = (A \cup B) \cap (A \cup \bar{B}) \cap (\bar{A} \cup B)$$
$$A \underset{DNF}{\cup} B = (A \cap B) \cup (A \cap \bar{B}) \cup (\bar{A} \cap B)$$
$$A \underset{CNF}{\cup} B = A \cup B$$

The final step is the construction of an evidence set from the $n_d^2 - n_d$ IVFS obtained from (12) and (13). At the onset, the user specifies the relative weight of the n_d databases utilized,

m_k, which form a probability restriction since the sum of all m_k for k=1...n_d must equal one.

When two fuzzy sets $f^{d_k}(x)$ and $f^{d_l}(x)$, with relative weights m_k and m_l respectively, are combined with (12) and (13) to obtain two IVFS, the total weight ascribed to this pair of IVFS is $(m_k + m_l)/(n_d - 1)$, and half of this quantity to each IVFS, which guarantees that the several IVFS are weighted by a probability restriction. Thus, if we have n_d databases, with probability weight m_k (k=1...n_d), the evidence set membership function for an answer "YES" to concept x_i of knowledge space X, is given by:

$$ESf_{YES,x_i}(x) = \left\{ \left\langle IVf_{YES,x_i}^{d_k \cup d_l}(x), \frac{m_k + m_l}{2(n_d - 1)} \right\rangle, \left\langle IVf_{YES,x_i}^{d_k \cap d_l}(x), \frac{m_k + m_l}{2(n_d - 1)} \right\rangle \right\}, \; k,l = 1...n_d$$

that is, the evidence set has $n_d^2 - n_d$ focal intervals constructed from (12) and (13), weighted as described above. When several focal intervals coincide, their weights are summed and only one interval is acknowledged. The procedure for the "NO" evidence set is equivalent. Figure 3 depicts the construction of the "YES" evidence set membership function for a case of n_d=2.

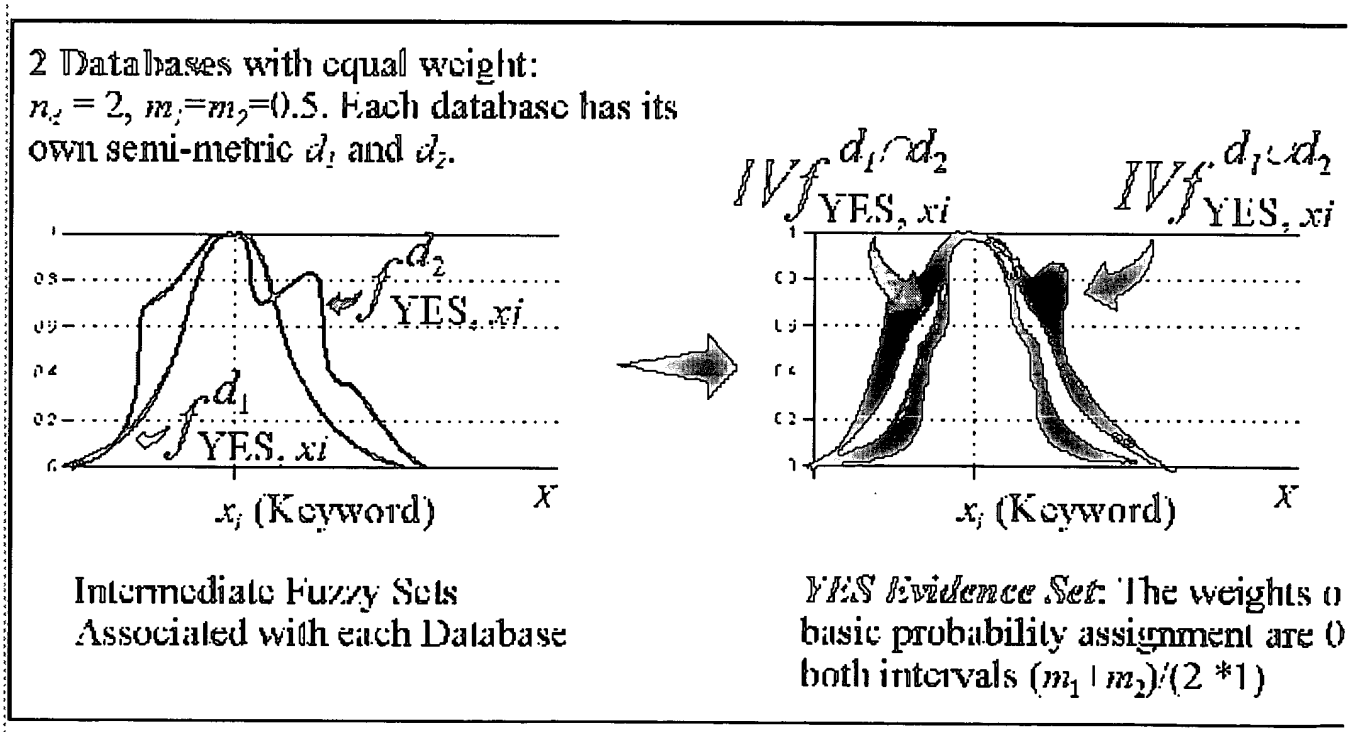


Figure 3: Evidence set membership function for answer "YES" to concept x_i

The two different semi-metrics d_1 and d_2 for the knowledge space X cause the category constructed for the "YES" answer to concept x_i to be more than just fuzzy, also nonspecific and conflicting. It is important to stress that this more accurate construction of prototypical

categories includes more uncertainty forms as a result of structural differences in the information stored in the several distributed memory contexts utilized. It is the lower level conflicts of long-term memory that the short-term construction of categories tailored by users reflects. This algorithm, implements many of the, temporary, "on the hoof" [Clark, 1993] category constructions ideas as discussed previously. In particular, it is based on a long-term memory bank of semantic relations that reflects the conceptual relationships of the community of users. Prototype categories are then built using evidence sets which reflect such consensually built relational metrics and the directed interest of a particular user at a particular time.

9.3 Document Retrieval

After construction of the learned category $A(x)$, the system must return to the user the properties (data records such as books) relevant to this category. Notice that every property p_i defines a crisp subset of the total knowledge space X whose elements are all the concepts to which p_i is directly connected in any of the constituent databases. Let this subset be represented by $S_{p_i}(x)$. Since each property defines a crisp subset of X, the similarity between this crisp subset and the evidence subset defined by the learned category is a measure of the relevance of the property to the learned category. One way to define this measure of similarity is to approximate the evidence set category to its closest fuzzy set by a process of elimination of nonspecificity and conflict. Once this fuzzy set is obtained the following measures of similarity between properties and learned categories can be defined:

$$R_1(p_i) = \frac{\sum_{x \in X} A(x) \cap S_{p_i}(x)}{\sum_{x \in X} S_{p_i}(x)}$$

and

$$R_2(p_i) = \frac{\sum_{x \in X} A(x) \cap S_{p_i}(x)}{\sum_{x \in X} A(x)}$$

R_1 yields the fuzzy cardinality of the fuzzy set given by the intersection of the learned category $A(x)$ with $S_{p_i}(x)$ over the cardinality of the latter: it is an index of the subsethood of $S_{p_i}(x)$ in $A(x)$. The more $S_{p_i}(x)$ is a subset of $A(x)$, the more relevant p_i is. As long as $S_{p_i}(x)$ is included to a large extent in A, the property p_i will be considered very relevant, even if the learned category contains many more concepts than those included in $S_{p_i}(x)$. This way, R_1 gives high marks to all those properties who form subsets of the learned category and not necessarily those properties that qualify (are related to) the entire learned category as a whole. It is an index that emphasizes the independence of the concepts of the learned

category. It should be used when the cardinality of $A(x)$ is large, otherwise, very few properties will exist that qualify such large set of concepts.

R_2, on the other hand, yields the fuzzy cardinality of the fuzzy set given by the intersection of the learned category $A(x)$ with $S_{p_i}(x)$ over the cardinality of the former: it is an index of the subsethood of $A(x)$ in $S_{p_i}(x)$. The more $A(x)$ is a subset of $S_{p_i}(x)$, the more relevant p_i is. This way, R_2 gives high marks to all those properties who form subsets that include the learned category as a whole. It is an index that emphasizes the dependence of the concepts of the learned category. It should be used when the cardinality of $A(x)$ is small.

Thus, after the system finishes its construction of the learned category $A(x)$, the user can select one of the indices given by (15), (16), or a combination of the two and a value between 0 and 1. High values will result on the system returning only those properties highly related to $A(x)$ according to the index chosen. Lower values will result in many more items being included in the list of returned properties.

9.4 Adaptive Alteration of Long-Term Structure by Short-Term Categorization

It is also desirable to provide this system with a mechanism to adapt the long-term relational structure, the knowledge space, according to the system's interactions with its users. Due to the properties (data records) it stores, the system may fail to construct strong relations between concepts (keywords) that its users find relevant. Therefore, the more certain concepts are associated with each other, by often being simultaneously included with a high degree of membership in learned categories, the more the distance between them should be reduced. An easy way to achieve this is to have the values of $N(x_i)$ and $N(x_i, x_j)$ as defined in (8), adaptively altered for each of the constituent n_d databases. After an evidence set learned category is constructed and reduced to a fuzzy set $A(x)$, these values can be changed to:

$$N_{t+1}^{k}(x_i) = N_t^{k}(x_i) + A(x_i),\ k = 1...n_d,\ x_i \in X$$

and

$$N_{t+1}^{k}(x_i,x_j) = N_t^{k}(x_i,x_j) + \min[A(x_i),A(x_j)],\ k = 1...n_d,\ x_i \in X$$

respectively (t indicates the current state and $t+1$ the new state). This implements an adaption of the system to its users according to repeated interaction. Thus, the system though constructing its categories according to its own distributed long-term memory, will adapt its constructions as it engages in question-answering conversations with its users. The direction of this adaptation leads the system's relational structure to match more and more the expectations of the community of users with whom the system interacts. In other words, its constructions are consensually selected by the community of users. Furthermore, when two highly activated concepts in the learned category are not present in the same database

(each one exists in a different database) they are added to the database which does not contain them, with property counts given by equations (17) and (18). If the simultaneous activation keeps occurring, then a database that did not previously contain a certain concept, will have its presence progressively strengthened, even though such concept does not really possess any properties in this database.

If we regard the system's learned categories, implemented as evidence sets, as linguistic prototypical categories, which are the basis of the system's communication with its users, then such categories are precisely a mechanism to achieve the structural perturbation of its long-term distributed memory in order to lead it to increasing adaptation to its environment. In addition, short-term memory not only adapts an existing structure to its users, but effectively creates new elements in different, otherwise independent, relational databases, solely by virtue of its temporary construction of categories This way, linguistic categories function as a system of consensual structural perturbation of distributed memory banks, capable of transferring information across different contexts. This pragmatic adaptation to an environment has been argued to function as a model of an evolving semiosis between cognitive systems and their environments which validates a position of Evolutionary Constructivism [Henry and Rocha, 1996; Rocha, 1997a, 1997b].

9.5 *TalkMine*: The Implemented Application

An application named *TalkMine* was developed that implements the above specified system. The example shown below refers to a database of 150 books. From the pool of 150 books three databases were created by randomly picking books from this pool with equal probability. Each sub-database is comprised of about 50 books, some of which exist in more than one of the sub-databases. Book records are the properties of the system described above. The fields created for these records were Title, Date, Authors, Publisher, plus 6 key-words describing the contents of the books. These keywords are the concepts of the system described above. Naturally, many of these keywords overlap. From the 150 books, 89 keywords were identified. Thus the system has 89 concepts and 150 properties. Figure 4 shows *TalkMine*'s result screen. Two databases are selected *S3.DBD* and *S4.DBD*. In this case the initial concept to start the search was "ADAPTIVE SYSTEMS". The concepts (key-words) used in the question-answering process are shown in two different boxes for questions receiving "YES" and "NO" responses respectively.

TalkMine implements the contextual construction of short-term categories from several long-term relational structures as described above. It is based on prototypical categories represented by evidence sets defined in section 5. The long-term distributed memory structure implements the connectionist aspects of cognitive systems. It is this structure that ultimately dictates how categories are constructed. The categories constructed are short-term structures not stored in any location, but constructed "on the hoof" as the system relates its several sub-networks to the interaction (conversation) users provide. Its syntax is based on evidence sets and their extended theory of approximate reasoning. Semantics is established in accordance to the system's internal distributed semi-metrics, and how it pragmatically relates to the users needs. Furthermore, *TalkMine* explores contextual conflicting uncertainty as a source of artificial category construction, since the selection of concepts for the question-answering process is based on reducing the total uncertainty present in learned categories. More details about *TalkMine* can be found in Rocha [1997b].

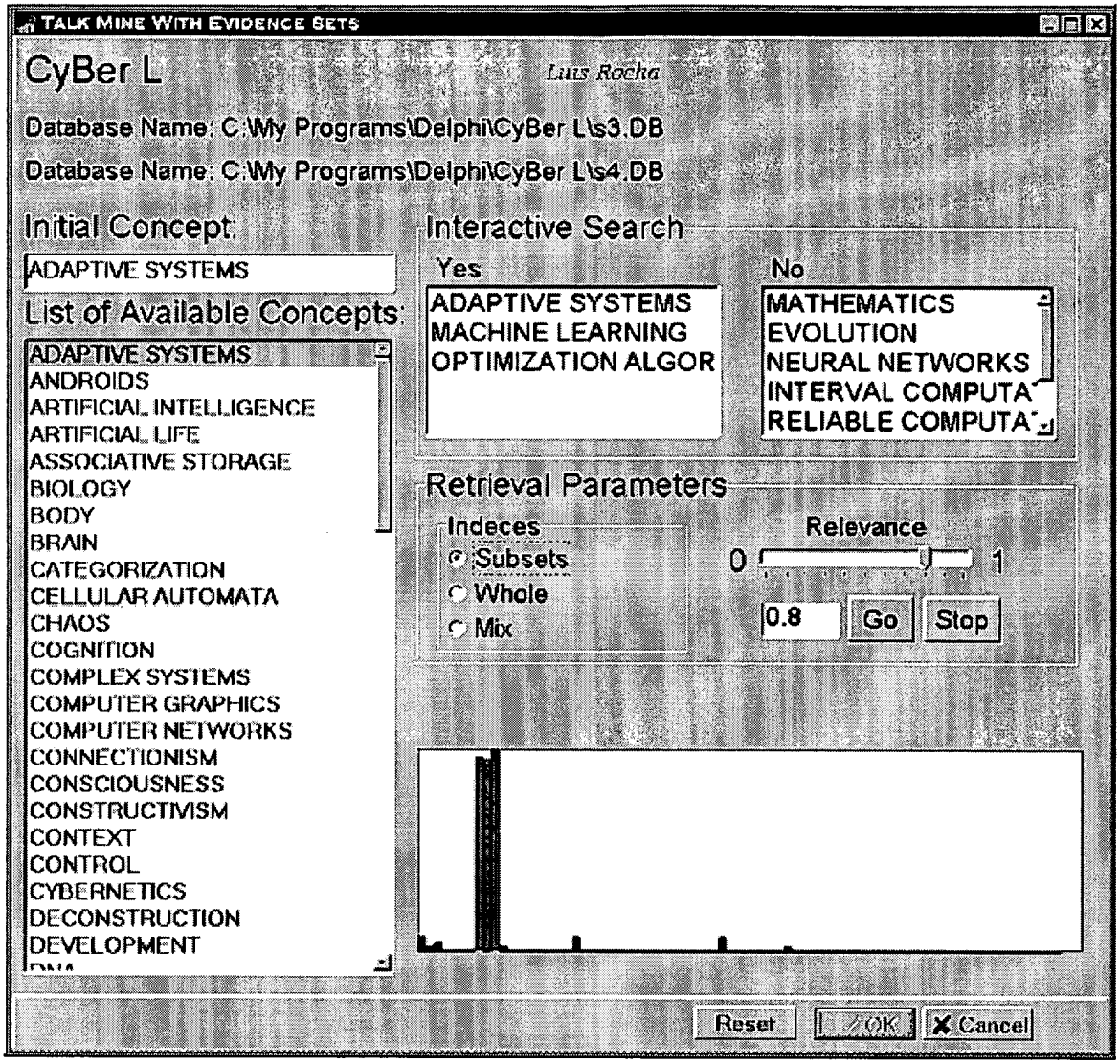


Figure 3: *TalkMine*'s search screen

10 Evidence Sets as a system of Recontextualization of Categories

The evidence set question-answering system of section 9 models the construction of the prototypical effects discussed in section 4. Such "on the hoof" construction of categories triggered by interaction with users, allows several distributed networks to be searched simultaneously, temporarily generating categories that are not really stored in any location. The short-term categories bridge together a number of possibly unrelated contexts, which in turn creates new associations in the individual databases that would never occur within their own limited context. Therefore, the construction of short-term linguistic categories in this artificial system, implements a sort of structural perturbation of long-term distributed associations. It is in fact a system of recontextualization of otherwise contextually constrained, independent distributed networks.

This transference of information across dissimilar contexts through short-term categorization models some aspects of what metaphor offers to human cognition: the ability

to discern correspondence in non-similar concepts [Holyoak and Thagard, 1995; Henry, 1995]. Consider the following example. Two distinct databases are going to be searched using the system described above. One database contains the books of an institution devoted to the study of computational complex adaptive systems (e.g. the library of the Santa Fe Institute), and the other the books of a Philosophy of Biology department . I am interested in the concepts of Genetics and Natural Selection. If I were to conduct this search a number of times, due to my own interests, the learned category obtained would certainly contain other concepts such as Adaptive Computation, Genetic Algorithms, etc. Let me assume that the concept of Genetic Algorithms does not initially exist in the Philosophy of Biology library. After I conduct this search a number of times, the concept of Genetic Algorithms is created in this library, even though it does not contain any books in this area. However, with my continuing to perform this search over and over again, the concept of Genetic Algorithms becomes highly associated with Genetics and Natural Selection, in a sense establishing a metaphor for these concepts. From this point on, users of the Philosophy of Biology library, by entering the keyword Genetic Algorithms would have their own data retrieval system output books ranging from "The Origin of Species" to treatises on Neo-Darwinism - at which point they would probably bar me from using their networked database! Because of the Evidence Set system of short-term categorization that uses existing, fairly contextually independent distributed sub-networks, an ability to create correspondence between somewhat unrelated concepts is established.

Given a large number of sub-networks comprised of context-specific associations, the categorization system is able to create new categories that are not stored in any one location, changing the long-term memory banks in an open-ended fashion. Thus the linguistic categorization Evidence Set mechanism implements a system of open-ended structural perturbation of long-term networked memory. Open-endedness does not mean that the categorizing system is able to discern all possible details of its user environment, but that it can permutate all the associative information that it constructs in an open-ended manner. Each independent network has the ability to associate new knowledge in its own context (e.g. as more books are added to the libraries of the prior examples). To this, the categorization scheme adds the ability of open-ended associations built across networks and contexts. Therefore, a linguistic categorization mechanism as defined above, offers the ability to recontextualize lower level distributed memory banks, according to a pragmatic, consensual, interaction with an environment.

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Footnotes

1. The membership value of an element of an evidence set is independent of the membership values of others elements contained in the set.

2. This measure of distance calculated in a large network of nodes, is usually not a Euclidean metric because it does not observe the triangular inequality. In other words, the shortest distance between two nodes of the network might not be the direct path. This means that

two nodes may be closer to each other when another node is associated with them. Such measures of distance are referred to as semi-metrics [Galvin and Shore, 1991].



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